US Army Corps
of Engineers
Construction Engineering
Research Laboratory

AD-A246 322

USACERL Technical Report E-91/12
September 1991

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Building Comfort Analysis Using BLAST: A Case Study

by
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This study demonstrates this unique BLAST feature by examining the comfort parameters at a new Air Force Housing (UEPH) facility at Lajes Field, Azores. The uncomfortably warm conditions of this building made the barracks a good case study for a comfort evaluation.

BLAST was used to assess the UEPH and to simulate the building under various hypothetical conditions. Program reports were compared to determine: (1) to what extent thermal comfort problems existed, (2) possible solutions to the identified problems, and (3) the relative energy burden of mechanically cooling the building versus cooling by mechanical ventilation.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1991	Final

4. TITLE AND SUBTITLE
Building Comfort Analysis Using BLAST: A Case Study

5. FUNDING NUMBERS
PE 4A162741
PR AT45
WU XG1

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratory (USACERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR E-91/12

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQUSACE
ATTN: CEMP-ET
20 Massachusetts Avenue, NW.
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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BLAST was used to assess the UEPH and to simulate the building under various hypothetical conditions. Program reports were compared to determine: (1) to what extent thermal comfort problems existed, (2) possible solutions to the identified problems, and (3) the relative energy burden of mechanically cooling the building versus cooling by mechanical ventilation.

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14. SUBJECT TERMS
BLAST | comfort analysis
buildings | Lajes Field, Azores

15. NUMBER OF PAGES
76

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

SUMMARY

This report describes a method for using a new feature of the Building Loads Analysis and Systems Thermodynamics (BLAST) computer program to examine a facility's comfort parameters. BLAST is a comprehensive hour-by-hour simulation program that can evaluate a facility's energy consumption, and that can now also produce information for a thermal comfort analysis. The BLAST thermal comfort component uses the industry standard: American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) parameters. The case study used a detailed model created from design documents of the new Air Force Unaccompanied Enlisted Personnel Housing (UEPH) facility at Lajes Field, Azores, and weather data obtained from the U.S. Environmental Technical Applications Center (USAF-ETAC) to estimate energy consumption using mechanical cooling.

In the "as-designed" facility, BLAST uncovered two significant problems:

1. The shading system did not sufficiently block solar radiation from entering the building.

2. The control methods used for the ventilation system were not configured optimally.

The comfort analysis showed that, under these conditions, the facility exceeded accepted thermal comfort conditions. BLAST models of the facility showed that low-cost corrective measures could be taken to overcome the uncomfortable conditions at the barracks.

Modeling the building under various conditions helped to analyze and resolve the solar load problem. An exterior shading screen produced the best thermal comfort alternative by intercepting both direct and diffuse sunlight. Possible solutions requiring minor building modification were: (1) applying window shading films, (2) adding vertical fins to complement existing overhangs, or (3) installing exterior shading screens.

Modeling the building under various ventilation conditions showed that lowering the thermostatic ventilation control set point and cycling the fans at night instead of the day, would cool the interior environment without mechanical cooling (air conditioning). The ventilation system controls may also be manually overridden for nighttime ventilation. Cooling by ventilation can be controlled either manually or automatically. These are both inexpensive system changes.

BLAST also modeled the facility with a four-pipe fan-coil to estimate the building's energy consumption as if it were mechanically cooled. A four-pipe system provides the best space conditioning control, but at a high cost and energy consumption. Study results show that, with lowered thermostatic controls on the ventilation motors, energy consumption would be approximately 17,200 Btu/SF/YR (British Thermal Units per Square Foot per Year). With the four-pipe fan-coil system, energy consumption increases to 34,600 Btu/SF/YR. These higher energy costs do not include the additional expense of replacing the existing two-pipe system, which is currently used only for heating.

This report concludes that the BLAST comfort analysis capabilities are applicable to many building and facility types. It also details a general procedure for using BLAST to diagnose and resolve facility comfort problems.

FOREWORD

This work was performed for two sponsors: (1) the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162741AT45, "Energy and Energy Conservation"; Technical Area A, "New Construction Design"; Work Unit XG1, "Energy Analysis Techniques for Design," and (2) the Department of the Air Force, Headquarters Military Airlift Command, Engineering and Construction Services (MAC/DEEE), under project WX9, Reimbursable Order No. DEEE-89-0001. Mr. Dwight Beranek, CEMP-ET was the HQUSACE technical monitor, and Mr. Michael Capenegro, MAC/DEE was the Air Force Project Monitor.

This research was performed by the Energy and Utility Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (USACERL). The principal investigator was Mr. Robert Nemeth. Mr. Gary Schanche is Acting Chief, USACERL-ES. The USACERL technical editor was Mr. William J. Wolfe, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Traditional energy analysis programs examine the energy consumption of new or existing facilities. More detailed energy analysis programs, such as BLAST,[1] attempt to accurately simulate the building's performance. Such programs might well be modified to include additional performance factors as indoor air quality prediction, moisture migration with resultant energy effects, and thermal comfort conditions. BLAST was recently modified to include parameters for thermal comfort.

It is valuable to the designer to examine the comfort conditions and energy consumption of any new or existing facility. When facilities are conditioned (i.e., heated or cooled), interior temperatures are one major component of occupant thermal comfort. A study of temperature alone is not enough to predict occupant thermal comfort. However, not all facilities are located where, by regulation, they may be mechanically cooled,[2] and not all facilities need mechanical cooling to maintain comfortable conditions. An analysis of building performance using several alternate cooling methods can help determine the most energy- and cost-efficient way to achieve thermal comfort.

BLAST can be used to examine many operational strategies before actual installation. Modeling building performance is much less expensive than constructing, modifying, or even changing simple ventilation strategies in occupied buildings. In this case study, BLAST was used to model the relatively new Unaccompanied Enlisted Personnel Housing (UEPH) facility at Lajes Field, Azores. The Department of the Air Force, Headquarters Military Airlift Command, Engineering and Construction Services (MAC/DEEE) had received complaints regarding heat inside the building, and there were requests for general waivers to mechanically cool this facility. These conditions made the UEPH an ideal candidate for BLAST's extensive thermal comfort modeling, and MAC/DEEE tasked the U.S. Army Construction Engineering Research Laboratory (USACERL) to perform an independent study of the UEPH facility.

Objectives

The objectives of this study were to demonstrate BLAST's capability to incorporate comfort parameters into a traditional energy analysis, and to specify the steps for using BLAST to evaluate any new or existing facility to find effective, practical, and inexpensive options to maintain thermal comfort.

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[1] JoAnn Amber, *Automated Building Design Review Using BLAST*, Technical Report (TR) E-85/03/ADA151707 (U.S. Army Construction Engineering Research Laboratory [USACERL], January 1985).

[2] *Architectural and Engineering Instructions (AEI)–Design Criteria* (Office of the Chief of Engineers [OCE], 13 March 1987).

More specifically, the purpose of this case study was to illustrate BLAST's ability to:

1. Simulate conditions at the UEPH to do a facility comfort analysis

2. Locate problems that make the facility uncomfortably warm

3. Model conditions at the facility with each proposed solution to the problems, and to do a comfort analysis under those changed conditions

4. Provide analyses that help to compare and choose between solutions to the problem of thermal discomfort, based on effectiveness, cost, and feasibility.

Approach

The following steps were taken to perform the case study:

1. A U.S. Air Force Environmental Technical Applications Center (ETAC) Computerized Energy Analysis Reference Year (CEARY) weather file was accessed and used to simulate annual weather conditions in the Azores.

2. A BLAST input "deck" was developed describing the UEPH facility, including the required input for comfort modeling. This information was taken from construction documents furnished by installations engineers.

3. Comfort parameters were set, assuming the ventilation system to be off.

4. The BLAST deck was run for a selected time period, and Predicted Mean Vote (PMV) values were observed.

5. Since solar radiation was identified as a primary cause for thermal discomfort, various shading and insulation alternatives were modeled, along with several different ventilation schedules.

6. The facility was also modeled using various mechanical cooling configurations.

7. The results of the BLAST analyses were compared, based on effectiveness and practicality. Recommendations were made for improving conditions at the Lajes UEPH, and steps were outlined for using BLAST to evaluate any existing facility with problems relating to thermal comfort.

Mode of Technology Transfer

Information regarding distribution of BLAST can be obtained by contacting the BLAST Support Office by phone: (800) UI-BLAST or (217) 333-3877; by U.S. mail: BLAST Support Office, 30 Mechanical Engineering Bldg., 1206 W. Green Street, Urbana, IL 61801; or by electronic mail at the following address: Support@blast.bso.uiuc.edu.

2 PROJECT DESCRIPTION

BLAST Model

To perform an in-depth thermal analysis of the UEPH, a detailed model was developed to describe the building to the BLAST program. Though simplified models can accurately measure a building's energy consumption, a more complex model is needed to enable observations of each inhabited zone. This complex model eliminates any possibility of "averaging" zone results that may have occurred in a simplified model.

USACERL was furnished with a set of construction documents, i.e., the working drawings used to construct the facility, specifications, and 90 percent submittal calculations. Assuming that the building was constructed as designed, the drawings contain adequate information to accurately model the physical aspects of the building.

Facility Description

The UEPH facility is a three-story barracks housing 200 occupants. It has a double-loaded corridor with bedrooms along the west side, and bedrooms and ancillary spaces (i.e., lounges, storage, stairwells, etc.) along the east side. The construction consists primarily of masonry bearing walls with an applied exterior insulation and finish system (EIFS). The first floor system is a slab on grade and the second and third floor systems are steel joists supporting a metal deck covered with concrete. The roof system consists of wood trusses with plywood sheathing and clay tile shingles. This system is separated from the third floor by a construction assembly similar to the second and third floor system. (Figure 1)

Projecting from the exterior walls and running the length of the building are 3-ft deep* overhangs located immediately above each floor's windows, evidently included to control solar radiation. The barracks' designers have addressed occupant thermal comfort by providing overhangs to reduce solar loads, and mechanical ventilation to move air and to provide comfortable conditions.

Zone Description

The UEPH facility was represented by 18 zones, five zones for each floor (for a total of 15 zones), two staircase tower zones, and an attic zone. The five zones on each floor consist of three bedroom zones, a corridor zone, and an ancillary space zone (i.e., offices, lounge, storage, etc.). (Figure 2) There is one bedroom zone on the west side of the building and two bedroom zones on the east side (separated by the ancillary zone). (Figure 3)

With each floor's spaces modeled separately, observations of space temperature differentials due to floor location could be made. The results from the comfort analysis indicate a temperature differential of approximately three to four degrees from first to third floor. The first floor remains cooler because the slab-on-grade acts as a heat sink.

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*1 in. = 25.4 mm; 1 ft = 0.305 m; 1 sq in. = 645.2 mm^2; 1 sq ft = 0.093 m^2; °F = (°C × 1.8) + 32

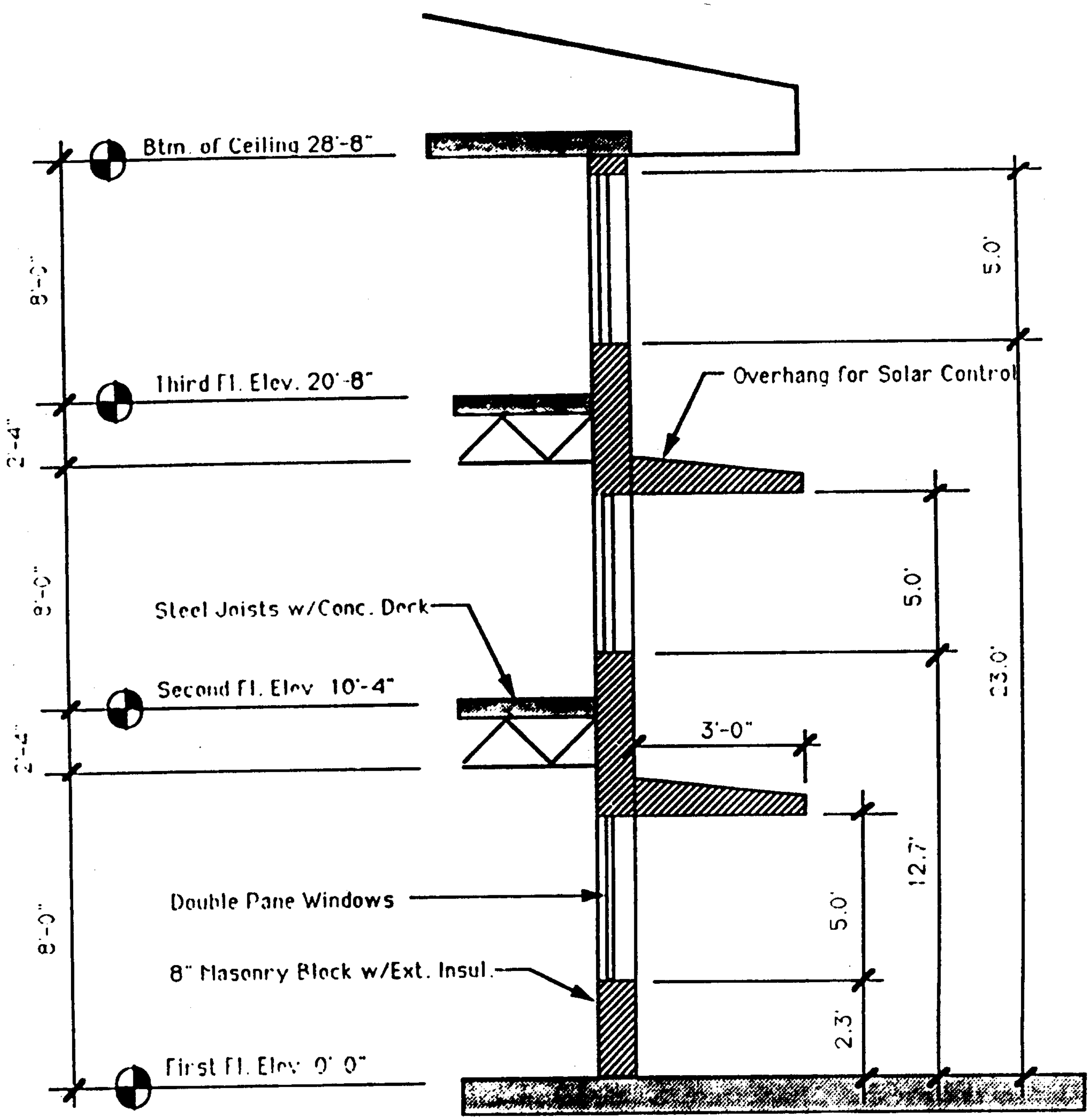


Figure 1. Typical Section Through Exterior Wall.

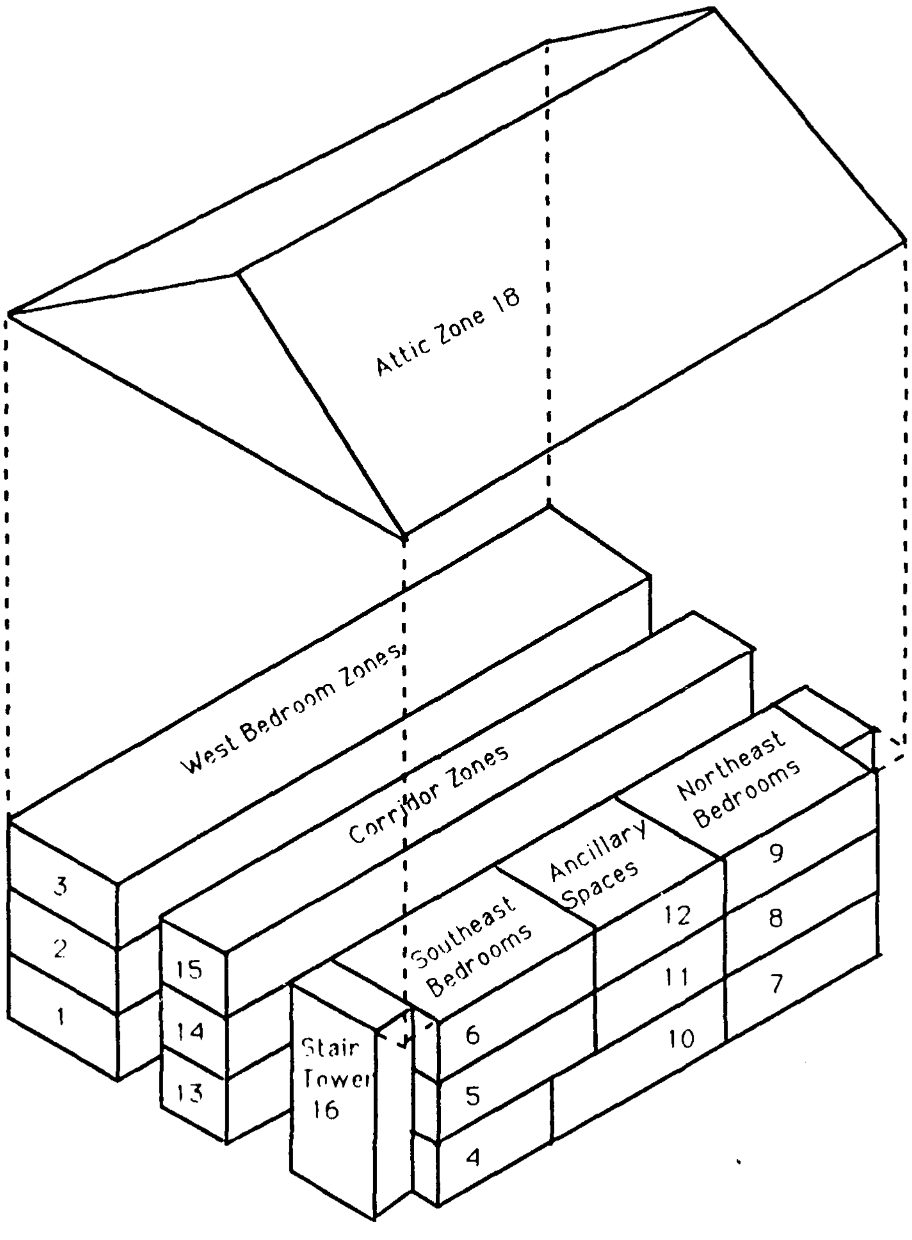


Figure 2. Isometric of Building Zones.

Throughout this study, references are made to the zones on the west side of the building. The UEPH's longitudinal axis is oriented approximately 35 degrees west of North; the zones facing west-southwest are referred to as the zones on the west side of the facility.

Window Modeling

The windows were modeled by grouping each zone's windows into continuous bands. Each band of windows is located directly below each floor's overhang. Figure 1 shows the vertical relationships of floors, windows, and overhangs, and also the vertical dimensions used in the BLAST model. Exact window specifications were not available for this analysis. The construction drawings indicate double pane windows and initial modeling uses a window configuration with a U-value of 0.553 (R=1.8, a double pane window with panes of 1/8-in. glass incorporating an airspace).

Internal Mass

Walls separating individual apartment units, and walls within the units themselves have been included as internal mass within each bedroom zone. There are slight differences between the separation walls and walls within units. The separation walls contain 2 in. of sound insulation; walls within units do not. This was included in the model.

Internal Loads

Two internal loads were modeled, "people" and electrical loads. The occupant activity level is assumed to be light office work; each person contributes 450 BTU/h to the total internal heat gain.

There is some heat gain from lighting. Bedroom zones have incandescent lights, and corridors use fluorescents. The lighting loads statement includes other miscellaneous loads in the rooms such as TVs, small refrigerators, stereos, etc. For each occupied zone, the analysis assumes 1.75 Watts/SF.

Schedules

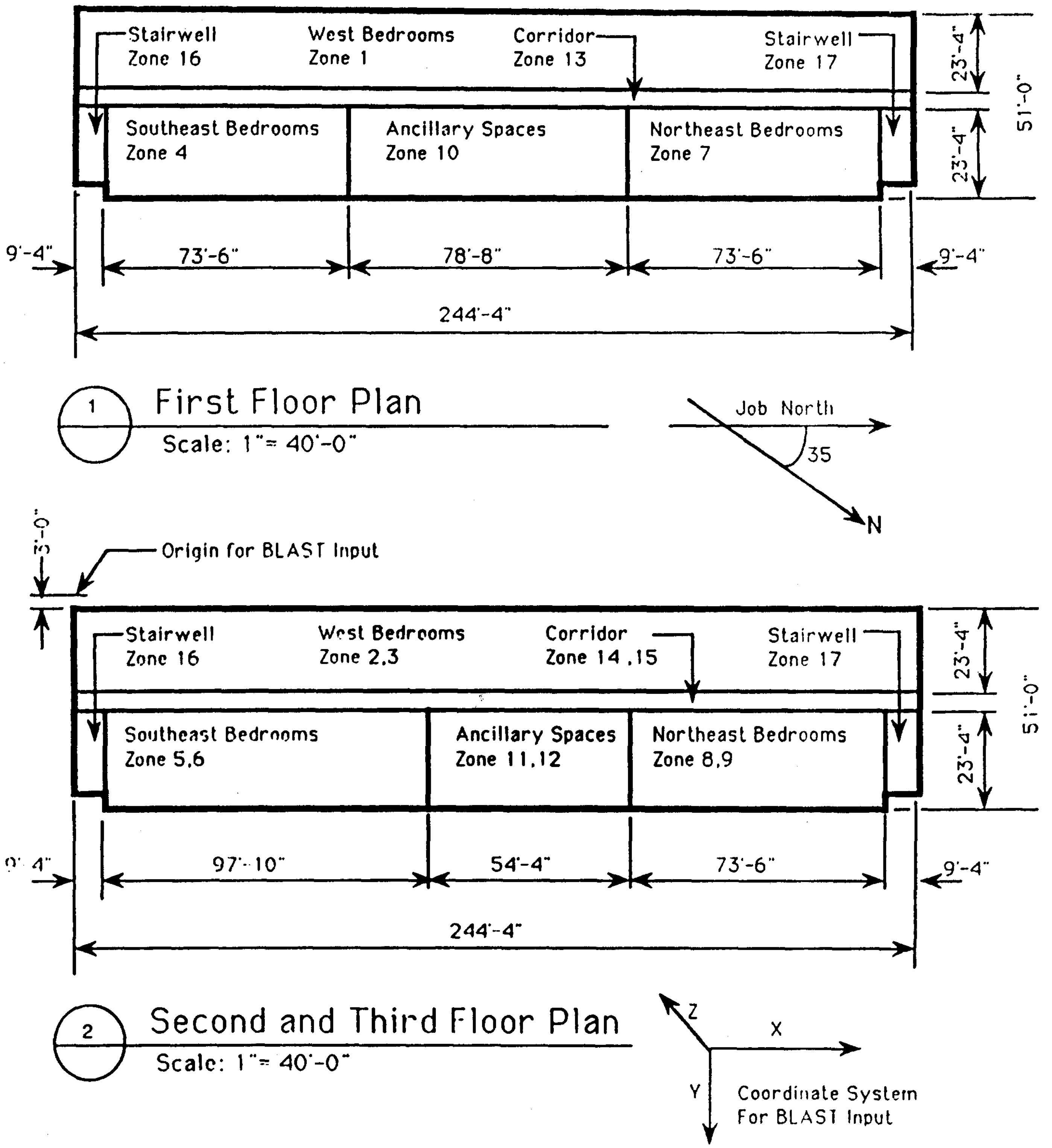
The BLAST program can place various internal loads and building mechanical systems on independent schedules. In the analysis, the schedules addressed:

1. Bedroom occupancies
2. Corridor occupancies
3. Bedroom lighting
4. Corridor lighting
5. Forced ventilation
6. System operation
7. Fan-coil operation.

The bedroom and corridor occupancies are an estimation of occupancy rates within these spaces. They should be a fair representation of the actual movement of people within the building. The building was assumed to be fully occupied at night and partly occupied during the daytime.

The lighting schedules control when lights are turned on and off. As housing units have relative little lighting heat gain, the contribution of lighting heat gain is not significant in the total building energy consumption.

The forced ventilation schedule controls when and how often the ventilation fans cycle. This forced ventilation is used, in BLAST, to model the space conditioning effects of directly introducing



Note: Zone 18 is an attic zone and covers the entire building

Figure 3. UEPH Floor Plans.

nonconditioned outside air to the space. The system and coil schedules control the mechanical system's operating hours and availability to supply heat or cooling.

Ventilation Modeling

To simulate the ventilation system (designed to mechanically cool the interior spaces by drawing exterior air through the rooms) a ventilation statement has been incorporated into each bedroom zone. This statement specifies the amount of air being drawn through and exhausted from each zone, and is controlled by the ventilation schedule.

The quantity of air being circulated through each zone was calculated by multiplying the number of rooms in a zone by 600 cu ft/min (CFM) per room to determine the total CFM per zone. The 600 CFM was determined through actual field measurements (supplied from MAC/DEEE).

The ventilation statement also specifies the temperature to which the simulation will attempt to regulate the zone. In the existing building, an in-duct thermostat controls the ventilation motors, and the set points are 74 °F.

Since the sole purpose of the ventilation system is to move quantities of air far greater than required by building codes, it is assumed that the ventilation system was meant to cool the building. The available analysis (and provided by MAC/DEEE) did not discuss the original design intent or any type of calculations. The original ventilation design (Figure 4) must have assumed that the exhaust system could maintain interior temperatures within a reasonable comfort range.

A large ventilation system may cause unacceptably high noise levels from air being drawn across the room air intake grill. Data from field tests show air movement at individual room intake grills of about 600 CFM, exhausted through a 14 x 8 in. duct (duct cross section = 112 sq in. or 0.778 sq ft), resulting in air movement of 771 ft/min (FPM) in the initial exhaust duct section. This rate of air movement has a potential for noise, particularly if ventilation rates are increased.

Air velocity is a function of location within the room. Close to the exhaust grill, room air moves at over 700 FPM. Assuming a fully open window at 9.75 sq ft and 600 CFM being drawn through the window, air movement through the window is approximately 62 FPM. The great variation of the air velocities, in two relatively close room locations, shows a need for measured data. Field verification of air velocities within a bedroom using a portable anemometer could eliminate speculation regarding air velocities within the space. Such studies may recommend optimal furniture layouts and room interior arrangements that locate occupants where they would experience greater air movement and less heat discomfort.

Comfort Modeling

To properly model and assess the thermal environment within the UEPH barracks, a combination of factors were taken into account. These factors fall under three headings:

1. Personal
2. Physiological
3. Environmental
   a. Weather influences
   b. Interior environment.

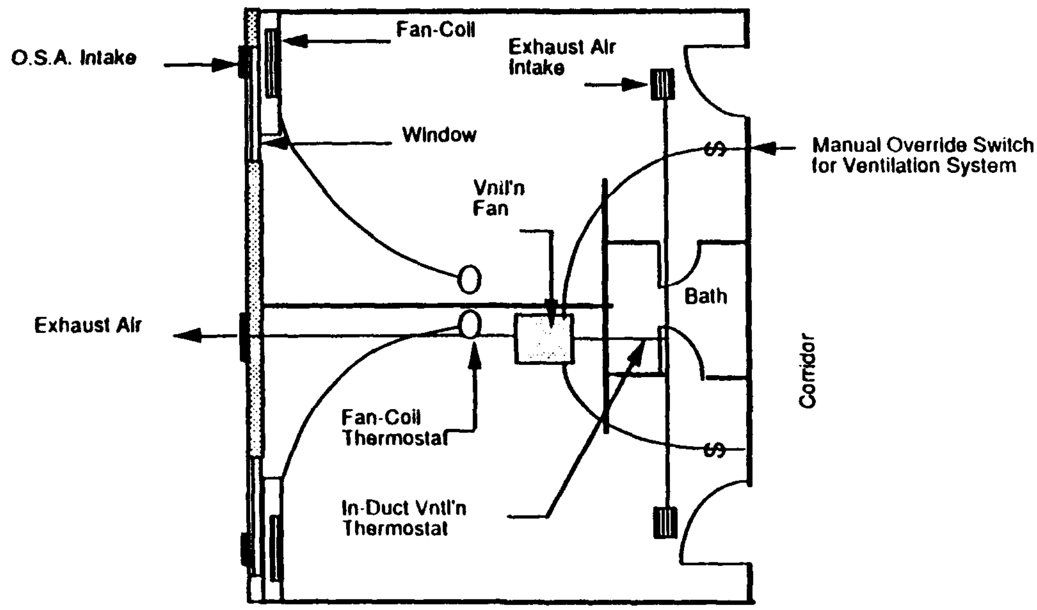


Figure 4. Ventilation System Layout.

Personal Parameters

For comfort analysis, two personal parameters that influence thermal comfort were considered: (1) metabolic rate (i.e., the rate at which the body produces heat), and (2) the thermal resistance of the clothing worn by an individual.

Personal parameters such as clothing and metabolic rate vary from person to person, thereby influencing individual perception of an identical environment. Even in an environment considered ideal by industry standards, some percentage of people will be uncomfortable. A large group of people seldom agree that a particular environment is entirely acceptable. Thus, values for clothing insulation and metabolic rates were adapted from accepted industry standards and treated as constants (throughout the day and the entire year) for the BLAST analysis.

Metabolic rates were specified as 1.2 Met Units (1 Met = 58.2W/m^2). This would be the equivalent of light office work or standing in a relaxed position. The clothing insulation value adopted for this analysis was 0.5 clo (1 clo = .88 Fft^{2}h/Btu), a value that reflects typical light summer attire. For more information regarding these variables see ASHRAE Standard 55-81R, *Thermal Environmental Conditions For Human Occupancy.*

Physiological Parameters

The physiological variables that influence a person's perception of thermal comfort are: (1) skin temperature, (2) core or internal temperature, (3) sweat rate, (4) skin wetness, and (5) thermal conductance between the core and the skin. BLAST calculates these values in the algorithm that defines the thermal comfort index.

Environmental Parameters

The environmental variables that influence the conditions of thermal comfort include: (1) air temperature, (2) mean radiant temperature, (3) relative air velocity, and (4) humidity. The temperature parameters are calculated during the computer simulation of the interior environment and passed to the algorithm that determines predicted thermal comfort. For each zone, the user must specify relative air velocity and humidity.

Naturally, it is the interior environmental conditions that are of interest for this analysis. However, due to the strategy used to cool the interior spaces, i.e., movement of large volumes of exterior air through the zones, exterior conditions directly affect the interior environmental conditions. Thus, it is important to examine climatic conditions in the Azores since these conditions so directly influence interior comfort in this facility, especially when natural ventilation is used to cool.

However, mechanical cooling, like that provided by a four-pipe fan-coil system, does not depend on exterior conditions. Comfort is solely a function of the mechanical system's ability to maintain desired interior temperatures.

Weather

An ETAC Computerized Energy Analysis Reference Year (CEARY) weather file was used for the annual simulations. Data from the weather file summary were used for design day simulations. The CEARY file represents a 15-year record period. Appendix A gives an overview of the weather data for the Azores. This data shows that the weather is not excessively hot (indicated by the relatively few cooling degree days of 621); however, the relative humidity is quite high (never below 70 percent).

For the initial design day runs, the following values were assigned to the climatic parameters: High=79.0, Low=65.3, WB=71.0, Date=21Sept, Prcs=401.50, WS=1319.03, Dir=191.23, Clearness=0.76, Weekday. BLAST uses this data to create a "typical" day (24 hours) with those weather conditions.

For the annual runs, no climatic parameters are specified, all climatic data are taken directly from the ETAC weather file. The simulation takes each hour (8760 hours per year) into account in the calculations.

Since the weather is assumed to be a given, and the occupant-related parameters are set at constant industry standards, the only variable parameters which apply to the issue of occupant comfort are interior climatic conditions.

Interior Conditions

The interior environmental parameters that need to be specified for the comfort analysis are relative air velocity and humidity. Temperatures (also used to determine comfort level) are taken directly out of the BLAST results for interior zone conditions. For the BLAST runs where the current ventilation system was modeled, the relative air velocity was assumed to be 50 FPM (i.e., when the ventilation fan is operating).

For the humidity parameter, two different modeling conditions (i.e., design days vs. annual runs) warranted unique humidity parameter specifications. For the design day runs, a constant relative humidity of 83 percent (derived from the ETAC weather data) was specified. This value was the average relative

warranted unique humidity parameter specifications. For the design day runs, a constant relative humidity of 83 percent (derived from the ETAC weather data) was specified. This value was the average relative humidity for June through September, and was used for the design day run comfort reports. Observation of Lajes weather data indicates that this is a conservative value, and that relative humidities are usually less than this. A conservative relative humidity value was selected to simulate "worst-case" conditions.

For the annual simulations conducted for the final report, relative humidity for the air within the zones was specified as either: (1) the same as exterior air (and correspondingly fluctuated with time) for the simulations using the existing ventilation system as a means of cooling, or (2) conditioned by the fan-coil system (with actual calculations of relative humidity being provided from the system simulation).

Predicted Mean Vote (PMV)

Three Thermal Comfort Models were recently incorporated into the BLAST program. These are the Pierce, KSU, and Fanger models. All three are well recognized models in ASHRAE literature and are similar in that all three apply an energy balance to a person and use the energy exchange mechanisms along with experimentally derived physiological parameters to predict the thermal sensation and the physiological response of a person due to the environment. The models differ somewhat in the physiological models that represent the human passive system (heat transfer through and from the body) and the human control system (the neural control of shivering, sweating, and skin blood flow). The models also differ in the criteria used to predict thermal sensation.

All three comfort models calculate a Predicted Mean Vote (PMV), which is an index of thermal comfort. Determination of PMVs is a complex mathematical function of activity, clothing, and the four environmental parameters. This analysis has relied on results obtained from the Pierce model since this method is superior in high humidity conditions when evaluating the cooling potential of sweat.

Thermal comfort predictions use the seven-point thermal sensation scale shown in Figure 5.

Thermal Sensation Scale

Figure 6 depicts the relationship between PMV and the predicted percentage of people dissatisfied (PPD). The comfort zone specified in the revised ASHRAE Standard 55-81R is based on 90 percent acceptance, or 10 percent dissatisfied (Figure 6). A PPD of 10 percent corresponds to the PMV range of ±0.5. Although this revision has not yet been adopted by ASHRAE, these assumptions represent a conservative basis for deciding comfort conditions.

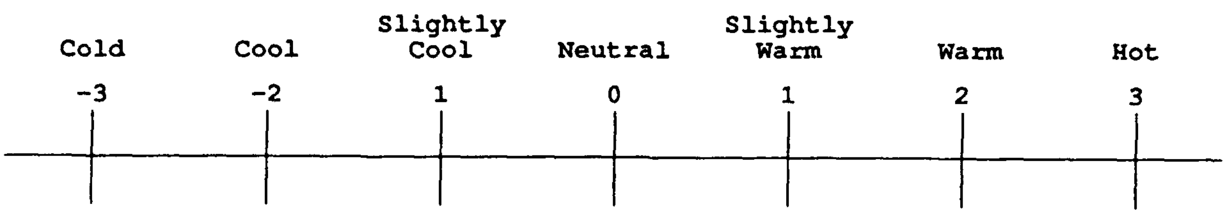


Figure 5. Thermal Sensation Scale.

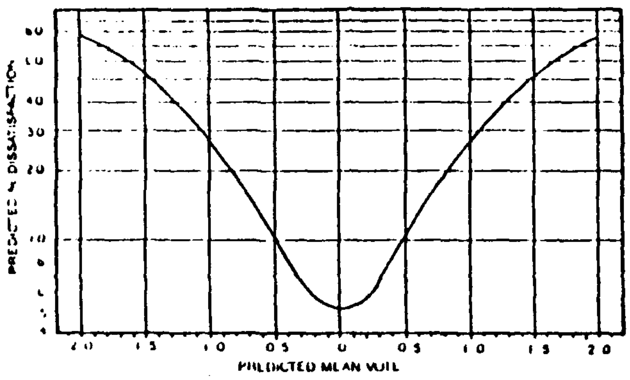


Figure 6. PPD as a Function of PMV.

3 BLAST ANALYSIS

The BLAST program is a true hour-by-hour program; for an annual simulation, 8760 separate building energy calculations are performed. The program can be configured to simulate as little as 1 day (i.e., Design Day Runs) to 1 full year. The following studies draw their conclusions from design day runs, 4-month simulations, and annual simulations. The design day runs were used primarily to study how varying certain parameters affected results. The 4-month simulations were used to generate results used for the summer season comfort analysis. July through October were the four months investigated, and September had the hottest conditions of the weather file year. The annual simulations were used primarily to compare the energy consumption characteristics of various mechanical and operational configurations.

Preliminary Studies

The detailed description of the UEPH facility examined: (1) the importance of air motion within the occupied zones, (2) the effects of adjacent spaces (such as attic and corridors) on the occupied zones, (3) the effects of solar insulation, (4) building orientation, and (5) building exterior finish. These studies were conducted with design day runs.

Air Motion Studies

Since the facility was designed to be cooled by moving large quantities of exterior air through the habitable zones, initial studies looked at the importance of air velocity on comfort. First, the UEPH was modeled as a closed environment. The purpose of this was to see what would happen if windows were left closed and the interior environment was allowed to fluctuate uncontrolled by a mechanical system, i.e., if the zone were at the mercy of the exterior environment. It would be reasonable to assume that these conditions could be approached by someone leaving his window closed in the morning and if the ventilation motor were disabled or inoperable.

Under this simulation, interior temperatures reached into the 90s in the second and third floor zones. The second and third floors differed markedly from the first floor since the first floor ground surface functions as a heat sink. This run clearly illustrated that if the windows were left closed and no air motion was induced in the zone, the interior environment would unquestionably be very uncomfortable.

Next, a similar run was conducted (i.e., with windows closed), but in this instance the interior air was induced to move at 50 FPM, as could be achieved with either a ceiling or portable fan. The purpose of this run was to establish the importance of air motion on human comfort in conditions with high air temperatures.

The results of this run indicate that inducing air motion can be both beneficial and detrimental to the perceived thermal comfort within a zone. In all zones except zone 3, the perceived thermal comfort improved. This improvement was greater in the lower floors than in the upper floors. In zone 3, perceived thermal comfort became worse. The results reveal that beyond a certain temperature, inducing air motion within a space is detrimental to the perceived thermal comfort. This is readily explainable in that when air temperature exceeds skin temperature, the only cooling benefit of increased air motion is due to the increased evaporation of perspiration from the skin. However, at higher temperatures, the human body will still experience a net sensible heat gain from the air and thus perceive an increase in discomfort, as indicated by the results.

The results from these two runs imply that the air motion induced by the ventilation motors would only be of benefit if temperatures were held below skin temperature. The perception of change will differ somewhat from individual to individual. Some people perspire more than others and will thus profit from a greater evaporative heat loss. When the air temperature is greater than skin temperature, there will be no heat loss by conduction (i.e., the air movement component), only by evaporation.

Following the initial two runs, thermostatic controls were incorporated to maintain interior temperatures between 68 and 78 °F. To determine air velocity influence at these lower temperatures, three BLAST runs were done, varying one parameter only—air velocity. The same quantities of air were moved through the zones, but the air velocity that an occupant would encounter was modeled at zero, 50, and 100 ft/min. These air velocities are a component in the thermal comfort equation. Air velocity had only a slight effect on occupant comfort. This is because air velocity has less influence on perceived thermal comfort in an acceptable temperature range. Since the results indicate only a one-half of one point deviation on the thermal comfort scale, later simulations used 50 FPM as a standard relative air velocity for comfort modeling.

The 50 FPM is also considered to be a fair representation of the air motion an individual would feel if inside a room with the ventilation fan running. These simulations implied that, if interior temperatures were held between a 68 and 78 °F range (without regard to how this was done), air motion will not greatly influence the thermal sensation that an occupant feels. Only at warmer temperatures would air motion become an important component of perceived thermal comfort. (Of course, at much cooler temperatures, people perceive increased air motion as "drafts.")

Adjacent Space - Temperature Influence

Initial BLAST results indicated relatively high temperatures within the corridor and attic zones. To study the effects of these zones on the habitable zones, ventilation statements were incorporated into these zone descriptions so that they could be ventilated and cooled. Three separate simulations were conducted: first only the attic was vented (two runs with different schedules); then attic and corridors were vented simultaneously.

The premise for ventilating the attic space was that, since the third floor was adjacent to a zone of high temperature, it may function as a heat sink for the attic zone. This simulation model assumed that, by ventilating the attic space, temperatures may be lowered in the third floor habitable zone.

Volume of the attic was calculated as approximately 73,200 cu ft (12 ft tall x 25 ft wide x 244 ft long). The ventilation rate was set at 10 air changes per hour. The resulting quantity of air being moved was 12,200 CFM. Two schedules for ventilation were simulated: the first used nighttime ventilation, and the second specified that the ventilation remain constant (i.e., remained on all the time). The difference between the two simulations was negligible.

Results from these simulations did not have as great an effect as anticipated. The predicted mean vote for zone three did not drop an appreciable amount, indicating that the insulation above zone three was already thermally isolating the two zones.

A later model incorporated a ventilation statement into the three corridor zones. The corridors were also ventilated to lower temperatures in zones adjacent to habitable zones. BLAST simulations revealed that maximum temperatures within the corridor zones were even higher than those in the attic. This is

because the roof radiates heat at night, cooling the attic, whereas the corridor traps heat. The corridors are contained within the core of the building and have very little envelope surface area exposed to the exterior, and are furthermore surrounded by relatively massive materials. The energy that the corridors absorb from the adjoining zones during the day can only be dissipated back to the same zones as they drop below the temperature of the corridor. As the habitable zones (i.e., bedrooms) drop in temperature in the evening, they are still subjected to energy gains from the walls adjoining the corridor. Now, instead of being subjected to heat gains from the exterior of the building, the bedrooms are subjected to heat gains from the interior of the building.

Corridor volume is approximately 8500 cu ft per floor. Ten air changes per hour were specified. The volume of air being moved through the hallway was 1416 CFM. Although ventilating the corridor did not result in significant changes within the habitable zones, the corridor temperatures did become much more tolerable. Since the corridor functions as a transition zone between the exterior and the bedrooms, subjecting building occupants to high interior temperatures before entering the bedrooms is undesirable. The lowering of corridor temperatures to acceptable levels would have a positive physiological and psychological effect upon persons entering the building, and possibly result in occupants also perceiving room temperatures as being more tolerable.

The results from these runs imply that ventilating hot spaces adjacent to the occupied zones does not significantly affect occupant comfort. However, ventilating the corridors would at least improve undesirable hallway conditions.

Air Source Concerns

Initial analysis assumed that the air being circulated through the rooms was from an exterior source, supplied either through the fan coil unit's fresh air intake damper and/or an open window. Specifications for the fan-coil unit revealed that the units are rated at 320 CFM with a 0-25 percent damper arrangement. The maximum amount of outside air that could be introduced into a room through a fan-coil unit is 80 CFM. If the ventilation system is intended to move 600 CFM, the remaining 520 CFM must be supplied from another source, either the hallway or from a window. The BLAST runs indicated that the hallway temperatures are quite high, therefore, making the hallways an undesirable source of makeup air.

To mimic the possibility that a window may be left closed in a zone and the ventilation fan cycled, a BLAST model was developed to simulate 80 CFM of air being drawn through the fan-coil unit and the remaining air being drawn from the corridor. Although the corridors have a window on each end, for the BLAST simulation to operate properly, exterior air had to be specified as infiltration into the corridor. This air served as makeup air. Moving large amounts of exterior air into the corridors caused the temperatures and perceived thermal comfort within these zones (i.e., the hallway) to change significantly. The perceived thermal comfort changed by two points (from 1.5 to -0.5) and the average temperature dropped over 10 degrees (from 83.9 to 71.6). Overall, corridor conditions were vastly improved.

Temperatures and perceived thermal comfort also dropped in the bedroom zones (i.e., became cooler), but not to the extent of the corridors. This particular result was not expected. Room temperatures were expected to rise (due to the introduction of warm corridor air) and corridor temperatures to fall. An analysis of the results determined that the corridor temperatures dropped to such a degree that there was a net heat loss (from the bedrooms) to the corridor rather than a heat gain as in the prior simulations. There is some question as to whether the results of this model will apply to the actual building. BLAST does not account for building pressurization or depressurization, and it is not clear how this air would be introduced into the corridors.

If corridors are to serve as an air source, they must be appropriately ventilated. This would also lower hallway temperatures to acceptable levels, itself an issue that accompanies the room comfort problem. The largest problem with using the corridors as the source of cooling air concerns fire safety and effectiveness of the source:

1. Fire code would require some type of fire damper be installed between the corridor and each room. This could be expensive to install and maintain.

2. Even more of a concern would be the location of air ducts from the corridor to the room. Since the exhaust system intake is located close to the doorway in the room, air allowed to migrate from the corridor to the room may simply short-circuit straight into the exhaust system without cooling the rest of the room.

These two points alone practically eliminate the corridor as an air source. Room windows seem to be the most logical location for the introduction of large quantities of air for ventilation purposes.

Another concern in the source of air used for cooling is the general building configuration. From examining the exterior elevation of the facility, it can be seen that the ventilation system's exhaust outlet is quite close to both intake locations (i.e., fan-coil unit and the window). There is a strong possibility that a portion of the exhausted air is simply being recycled through the rooms, counteracting some of the cooling potential of the ambient exterior air. This could particularly create problems on hot, windless days.

This phenomenon of ventilation short-circuiting should be further examined since this could be a serious detriment in using exterior air for cooling. If there is a sufficient wind present, the air turbulence on the exterior might eliminate the potential for short-circuiting. However, on a calm, hot day, the situation may not be the same. Various weather conditions could affect the ventilation system's effectiveness; i.e., the ventilation system may work better some times than others. All BLAST analyses assume the best possible conditions (i.e, that no short circuiting will occur).

Shading

As previously mentioned, the UEPH facility has four concrete overhangs (244 ft long by 3 ft deep). These are located directly above the first and second floor windows on the east and west walls and were cast integrally with a 3-ft tall concrete wall section. The third floor windows have a roof overhang that performs the same function as the lower concrete overhangs. The rest of the exterior walls are concrete block, glazing, and ventilation exhaust grills. Initial impressions are that the overhangs are there to give shade. However, if the building orientation is considered, it is apparent that the overhangs do not control solar radiation. If the building had been located with a direct east-west longitudinal axis, the overhangs would have reduced solar loads. However, the longitudinal axis of the building is approximately 35 degrees west of north (i.e., more north-south than east-west). As a result, the long sides of the building receive more low angle solar radiation than if the building were oriented east-west.

To effectively block this low angle radiation would require strategically placed vertical fins, not horizontal overhangs. In fact, vertical fins projecting from the building would have provided much better solar control, and would have been much simpler and cheaper to build than the horizontal overhangs. The overhang detail (Figure 7) and sun chart (Figure 8) illustrate how glazing exposure to solar radiation was determined. The cross-section illustrates the cutoff angle of the horizontal overhang. Any sun angle below 55 degrees will begin to fall upon the window surface. This angle is applicable to all windows with overhangs on the building, no matter what their orientation.

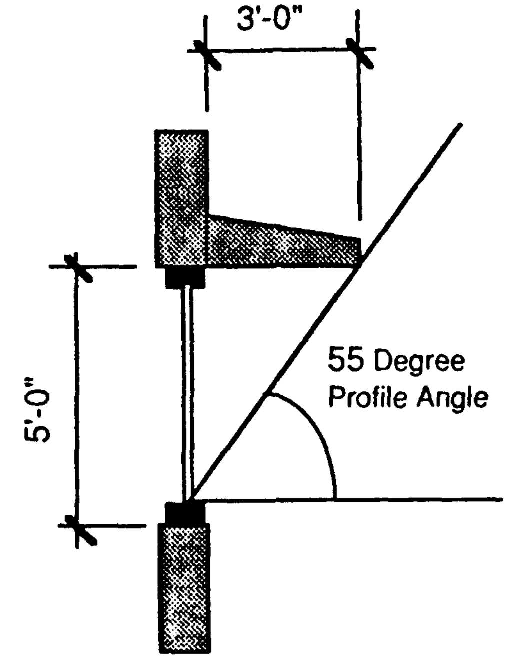


Figure 7. Overhang Profile Angle.

The Azores are at 38.77 degrees latitude; the sun angle charts used for this analysis are for 40 degrees latitude, close enough for this analysis. The sun chart indicates that a window oriented 55 degrees west of south, and 55 degrees east of north will always be shaded. During all time periods on the shaded portion of the chart, the sun will be (to some extent) striking the surface of the windows. At 35 degrees west of north, the west windows receive a significant solar load, especially during the warmer portions of the year. It comes as no surprise that the western zones are the warmest habitable zones in the building. Only at time periods to the right of the shaded area are windows successfully shaded by the horizontal overhangs; west windows rarely fall within the shaded area. As a result, the horizontal overhangs provide little solar control on the west side of the building.

To overcome the problem of orientation and to mitigate the effect of solar radiation, simulation of a shading film was applied to all windows to reduce solar radiation in habitable zones. The shading film resembled a Low-E glazing, with a transmission of 0.47, and a shading coefficient of 0.43. No particular brand of manufactured window was specified, only the properties of the window were manipulated.

Application of the window shading film had a great effect upon perceived thermal comfort and lowered corridor and ancillary space temperatures. Since habitable room temperatures were lowered, these spaces radiated less heat to adjoining spaces, yielding a net benefit not only to the bedrooms, but to neighboring spaces as well.

Building Exterior Finish

Two aspects of the building's exterior finish were examined: (1) the absorptivity (color) of the finish, and (2) the influence of the exterior insulation system. To investigate the effect of exterior finish

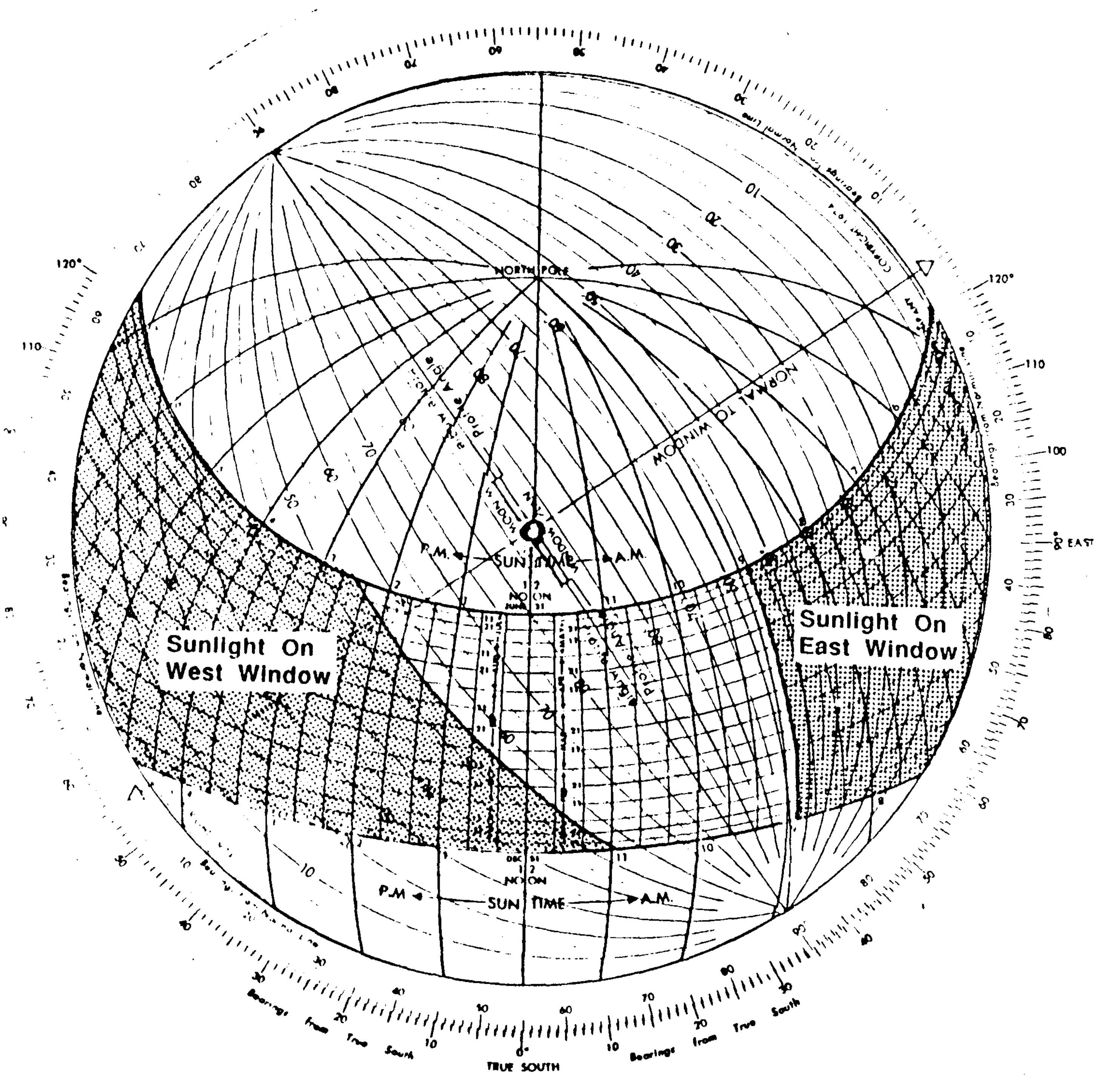


Figure 8. Sun Chart (40 Degrees N. Lat.).

color on interior conditions, two models were run: one with a completely reflective finish, and the other with a completely absorptive finish. Results from these simulations deviated very little from prior models.

Intuitively, this is not what would have been expected; however, once the building's construction is examined, the results start to make sense. The facility has an exterior insulation system with a stucco finish. As solar radiation falls upon the stucco finish, it heats up the exterior. The absorbed energy immediately encounters a layer of rigid insulation beneath the stucco. Therefore, the exterior skin of the building may experience a significant temperature rise; however, the exterior insulation beneath the stucco blocks most of this energy from reaching the building interior.

The absorptive exterior in this model may conflict with other cooling mechanisms. Since it is assumed that primary cooling within the building is achieved from air flow drawn from the exterior, it is also assumed that part of this same air will be drawn across the exterior surfaces of the building before entering the building. The hotter the exterior surface, the warmer the air entering the building will be. This, and the fact that the reflective exterior does slightly lower interior temperatures, indicate that a more reflective (lighter colored) than absorptive (darker colored) exterior surface is desirable.

To determine the effect of exterior insulation on interior conditions, a model without insulation was simulated. In this instance the stucco was applied directly to the concrete masonry units. The results from this simulation indicate that zone 3 remained cooler in the morning hours than in any of the other previous simulations. At night with the exterior insulation removed from the building, heat from the interior is allowed to conduct to the exterior rather than being trapped by the insulation. In all of the previous simulations (i.e., with insulation) the primary (and practically only) means of heat removal from the interior of the building was through ventilation. This is a rather slow means of heat removal since heat from the interior must be released by convection to the interior air and then expelled. By removing the insulation, the heat can be directly removed by conduction to the exterior environment as well as by interior ventilation. Although uninsulated masonry has a greater heat gain throughout the day, its potential to release energy at night is also greatly increased.

The only detrimental impact of removing the insulation (during the summer) is that zone three remains slightly warmer than the insulated model for a couple of hours in the evening. This is due to the solar radiation being able to warm the exterior walls instead of being blocked directly beneath the stucco finish.

Since the Azores only experiences about 1356 heating-degree days per year, results from this one run suggest that the exterior insulation finish system may not be necessary. There exists a distinct possibility that the stucco could have been applied directly to the CMUs, resulting in a thermodynamically improved building.

Building Orientation

Since the exact building orientation was not indicated on the set of construction drawings, two additional BLAST runs of the baseline model were executed. The building was rotated plus and minus 5 degrees to see what effect this would have on interior thermal comfort. The changes were insignificant. The conclusion that can be drawn from this is that, even if the orientation of the building as specified in BLAST differs from the model by a few degrees, the overall effect on the results is not significant.

Intermediate Studies

Following these first studies, research concentrated on the ventilation systems operation and on simple means to manage solar radiation heat gains. Various alternatives were studied to improve the interior environment without resorting to using chilled water to condition interior air.

Ventilation Strategy and Control Studies Emulating Current System Controls

This section of the study examined the control of the ventilation system. The existing system was modeled to create a baseline for comparison. The results from proposed alternatives could be compared to this particular model. Improvements to the interior environment due to proposed modifications could thus be illustrated. All results are for zone three (i.e., third floor, southwest side of building). Because these runs compare comfort conditions, energy consumption may or may not be exact (i.e., when infiltration is used to simulate the actual ventilation system, exact fan power requirements are not added into the consumption).

Initially, the UEPH model was reconfigured to simulate the system controls presently in operation. This required changing the ventilation controls to 74 °F with a 0 °F temperature differential between inside and outside. The system was placed on a constant-on schedule so that whenever the interior temperature rose above 74 °F , the ventilation system would energize and cycle until the space cooled to 74 °F.

To determine the extent of the fan system operation, two runs were conducted, one with and one without the fan generating an electrical load (Table 1). Since exhaust fans were being simulated, all fan heat is assumed to be exhausted with the removed air. It should be emphasized that these two runs produced identical results except for the electrical demand of the fans.

Column C indicates that the fan did not operate from 1200 to 1600 hours. Even though the zone temperatures were above 74 °F, the fan did not operate because interior temperatures had fallen below exterior temperatures. This was discovered to be a nuance of the BLAST program. BLAST has been programmed such that when cooling with ventilation, it compares interior tempertures to exterior temperatures (which are taken from the weather file being used for the simulation.) When interior temperatures are below exterior temperatures, it will de-energize the ventilation motor. In other words, BLAST knows that cooling will not occur by drawing in exterior air that is hotter than the air in the space already. BLAST automatically shuts off the ventilation fans until interior temperatures rise above exterior temperatures. In doing this, BLAST did not simulate the existing system. To imitate true ventilation fan behavior, an infiltration statement was incorporated into the program to introduce the same amount of air that the ventilation system would have drawn through the space had it operated. The infiltration statement is in effect from 1100 to 1500 hours and does not effect electrical loads, but does influence comfort, as would the actual ventilation system.

Note that the fan cycles between 20 to 30 percent, even at night (Figure 9). This is because the building's mass retains enough energy so that the ventilation system continues to shed heat intermittenly throughout the night.

Figure 10 illustrates the difference in zone temperatures due to the use of the infiltration statement from 1100 to 1500 hours. Even at night, temperatures never fall below 74 °F since the structure retains enough heat that the ventilation system continually attempts to cool it.

Table 1

UEPH Model of Fan System Operation

	A* W/Fan	B W/O Fan	C % Time	D Zone Temp.	E ODB	F PMV
1	5.522	3.412	30.54	74.00	67.08	0.13
2	5.130	3.412	24.86	74.00	66.40	0.13
3	4.867	3.412	21.06	74.00	65.85	0.11
4	4.685	3.412	18.42	74.00	65.44	0.11
5	4.573	3.412	16.80	74.00	65.30	0.08
6	35.820	34.120	24.60	74.00	65.57	0.13
7	4.810	3.412	20.23	74.00	66.26	0.11
8	4.857	3.412	20.91	74.00	67.49	0.08
9	5.257	3.412	26.70	74.00	69.27	0.08
10	6.614	3.412	46.34	74.01	71.33	0.08
11	1.032	3.412	99.97	74.48 >	73.66	0.14
12	3.412	3.412	0.00	75.74 <	75.85	0.35
13	3.412	3.412	0.00	76.26	77.49	0.56
14	3.412	3.412	0.00	76.64	78.59	0.70
15	3.412	3.412	0.00	77.33 <	79.00	0.85
16	23.970	17.060	100.00	78.77 >	78.59	1.02
17	23.970	17.060	100.00	78.90	77.63	1.11
18	23.970	17.060	100.00	78.25	76.12	1.04
19	23.970	17.060	100.00	76.92	74.34	0.81
20	23.970	17.060	100.00	75.64	72.56	0.60
21	23.970	17.060	100.00	74.51	71.05	0.42
22	22.460	17.060	78.15	74.01	69.68	0.27
23	6.839	3.412	49.59	74.01	68.59	0.19
24	6.069	3.412	38.45	74.01	67.77	0.16

*A - Electrical and fan load (KBTU)
B - Electrical load without fan load (KBTU)
C - % of time during the hour that fan operates
D - Zone 3 temperature (°F)
E - Outdoor dry bulb temperature (°F)
F - Pierce PMV (SET)

As the building currently functions, the ventilation fan operates by a simple in-duct thermostat, and would continue to draw in hot exterior air as long as the room temperatures are above 74 °F, without regard to exterior conditions. Although this method of operation moves air within the zone, its net effect is to make the building feel hot during the hottest portion of the day. Absorbed energy then dissipates, primarily through convection to the interior since the building is insulated on the exterior. Insulation effectively traps heat; exterior walls cannot conduct or radiate heat to the outside. Once zone temperatures fall to 74 °F, the fan shuts off. Since the nighttime temperature differential between the interior and exterior is only about 10 °F, the zone temperatures do not decrease below 74 °F unless occupants manually turn on the fans.

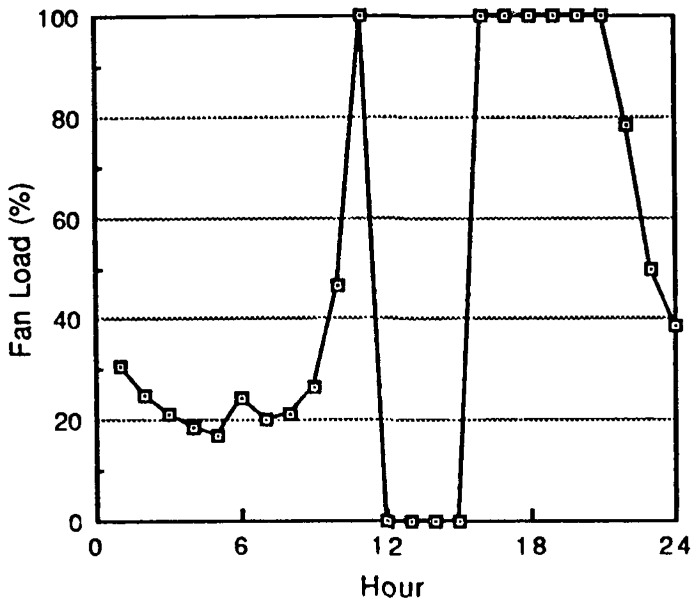


Figure 9. Fan Load Using Ventilation Statement.

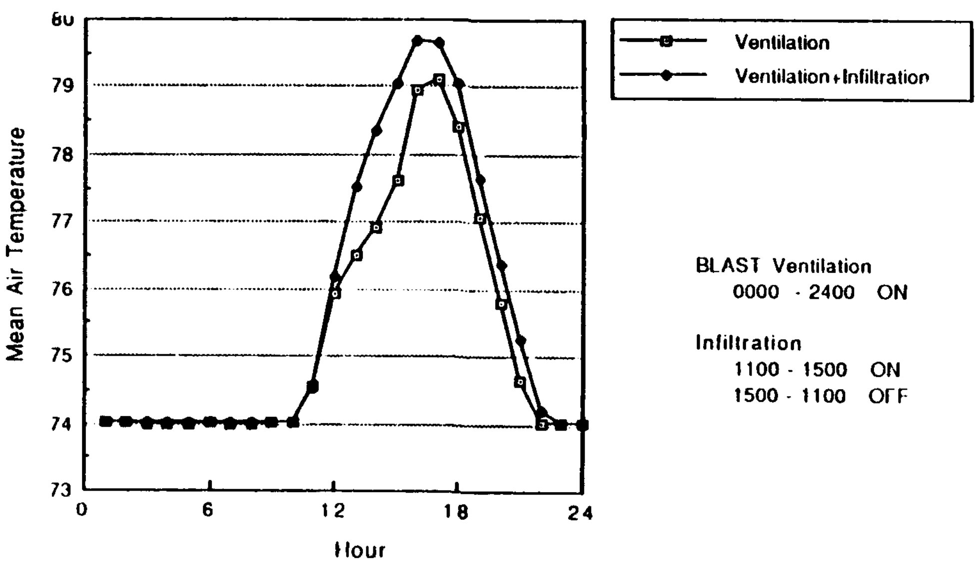


Figure 10. BLAST Ventilation With Infiltration Statement.

Modified Ventilation Control Simulations

Three modifications to the existing ventilation system were simulated to examine their effect on zone temperatures and PMVs:

1. Programmed nighttime ventilation
2. Constantly cycling ventilation fans
3. Changing thermostat set point to 65 °F (i.e., lowering it 9 °F).

Programmed Nighttime Ventilation. Ventilation schedules have been altered to:

1. 1800 to 0700 - ON (i.e., nighttime ventilation)
2. 0700 to 1800 - OFF.

Constant Ventilation. For this simulation, constant ventilation was achieved by using an infiltration statement instead of a ventilation statement. The infiltration was specified as constant throughout the day, and of a magnitude equal that of the ventilation system. Use of the infiltration statement causes the program to simulate the existing system in the respect that the (hypothetical) system will not shut off when interior temperatures drop below exterior temperatures. Results from this run simulate conditions if occupants were to operate their fans constantly.

Thermostat Set Point = 65 °F. This simulation changed the set point of the in-duct thermostat from its current 74 °F setting to 65 °F (Figure 11). This change takes advantage of lower nighttime temperatures to cool the interior building mass. As a result, the building can absorb more heat during the day without reradiating it to interior spaces.

Operating the ventilation system this way is not much different from programmed nighttime ventilation, except that the fan will attempt to cool the interior to a lower temperature and will continue to operate into the morning until exterior temperatures exceed interior temperatures.

Results from the above three simulations (plus the simulation modeling the existing ventilation system) are portrayed in Figures 12, 13, and 14. These graphs illustrate the differences in mean air temperature, predicted mean votes, and mean radiant temperatures of all four ventilation strategies.

Comparison of these measurements reveals that lowering the thermostat set point to 65 °F was the most effective method. Two runs were conducted to determine how often and to what extent the fans cycled with this control strategy (Table 2).

Figure 11 compares fan load with set points at 74 °F and 65 °F. The fan operates approximately 47 percent of the time with the set point at 74 °F and 75 percent of the time at 65 °F.

Two potential problems with lowering the thermostat set point would be the increased energy consumption and potential over-cooling of occupants during the night. The increased energy consumption could be addressed by limiting the ventilation system to its current usage, but changing the times during which it runs. The overcooling issue is best addressed by observing the PMVs for the various runs.

Readjusting the set point to 65 °F lowers the nighttime bedroom temperature to 69 °F. Thus, by changing the set point of the ventilation system's thermostat, a 5 °F drop in zone temperatures is achieved.

This, in effect, lowers the temperature of the internal mass, allowing it to absorb more heat during the day. An air temperature of 69 °F falls just outside comfort zones on psychometric charts for summer comfort zones. Although the air temperature may fall to 69 °F, the mean radiant temperature (MRT) stays well above 69 °F due to the energy contained within the thermal mass of the structure. This is important since the body exchanges heat with the surrounding environment through both convection and radiation. If the mean radiant temperature is well above the air temperature, as in this case, simply observing air temperature can lead to erroneous conclusions.

Figure 14 shows the noticeable difference between mean radiant temperatures using various ventilation control schemes. This graph and the Figure 13 graph are better indicators of expected occupant comfort than simply observing mean air temperatures.

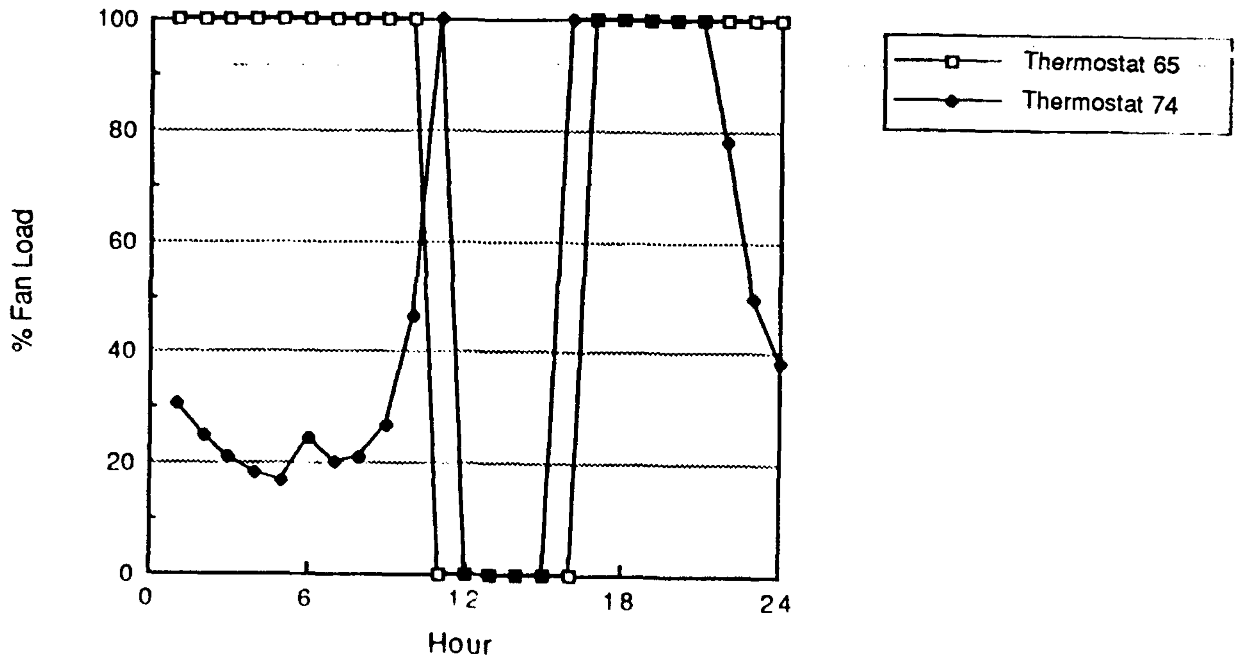


Figure 11. Fan Load for Two Set-Point Temperatures.

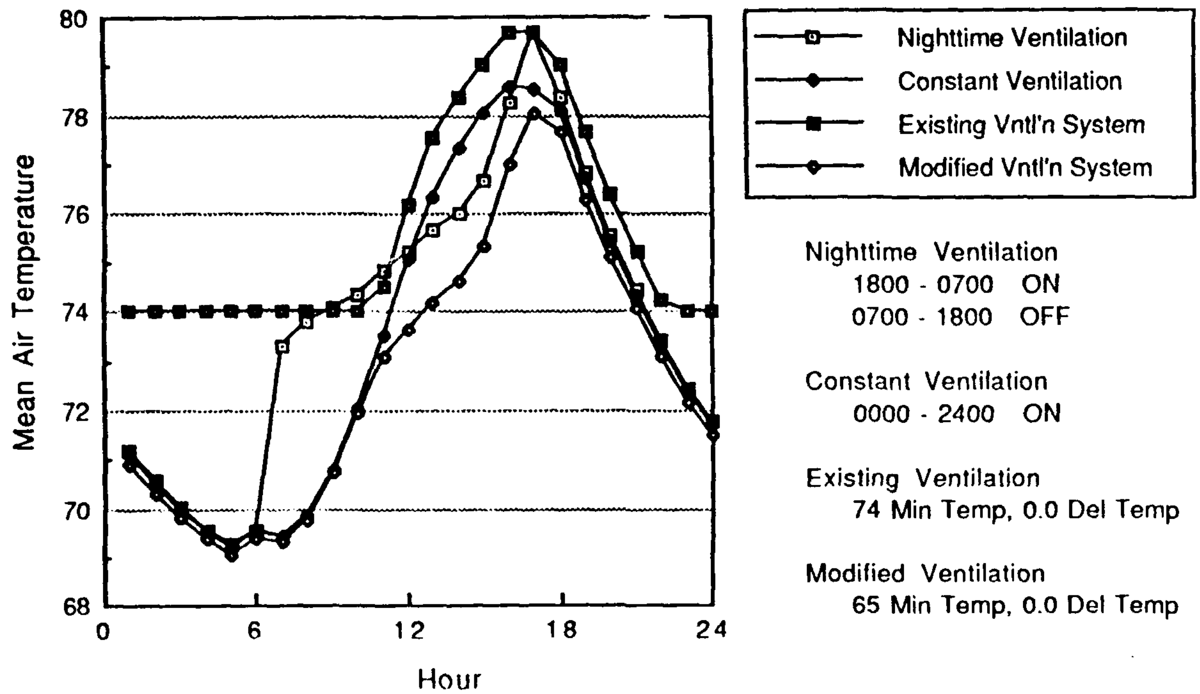


Figure 12. Mean Air Temperature Using Various Ventilation Methods.

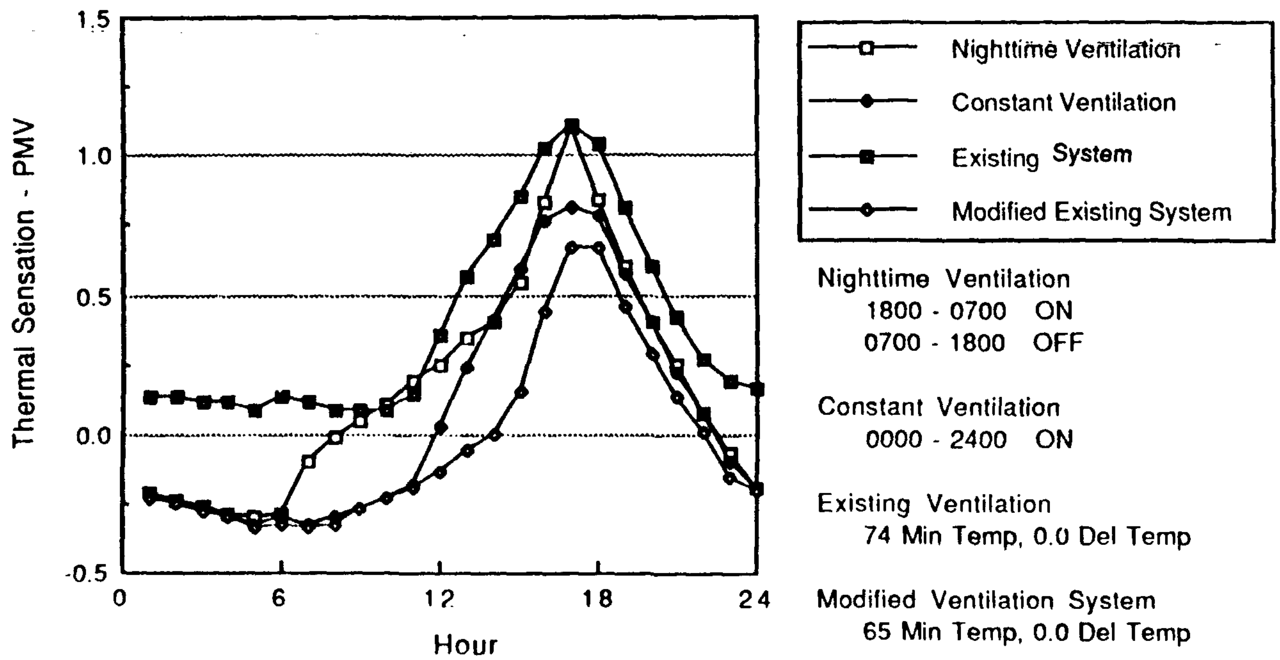


Figure 13. Pierce PMVs for Various Ventilation Strategies.

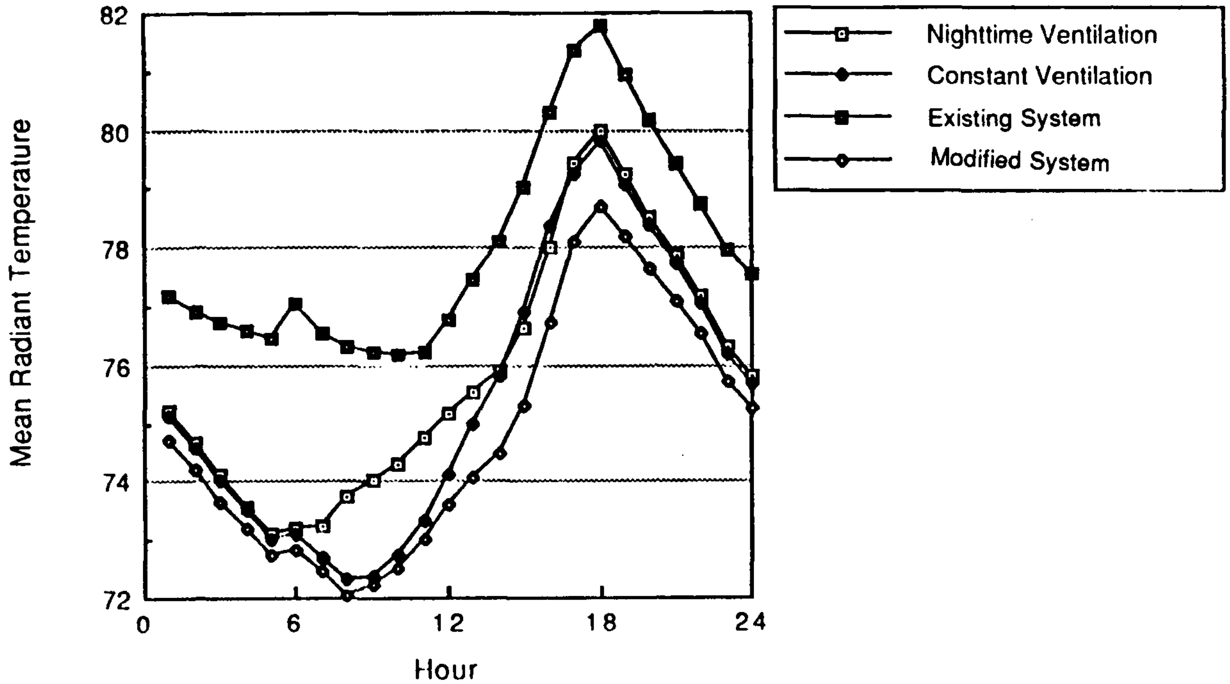


Figure 14. Mean Radiant Temperature Using Various Ventilation Methods.

Ventilation Modification Suggestions

The control strategy simulations clearly illustrate that alternative methods of control can be employed to lower room temperatures if so desired. Various types of controls can accomplish nighttime ventilation:

1. A simple timer may operate fans during preselected (and preferably occupant adjustable) hours.

2. An outside thermostat can turn on the fans when outdoor temperatures fall below 74 °F and shut off the fans when temperatures rise to 74 °F in the morning (i.e., opposite the controls presently in existence). This strategy would also require an interior thermostat to act as a lower-limit control to avoid overcooling occupants.

3. Thermostat set point could be lowered to 65 °F so that cool nighttime air would be drawn into the zones.

All systems would still require an override switch so that occupants could manually control the fans when so desired. Of prime importance is educating the building occupants to operate the existing system for maximum benefit. This would involve manually overriding the in-duct thermostatic controls to run the fans at night or to shut them off during the day.

Table 2

Modeled Fan Cycle Operation With Lowered Set Point

Hr	A W/Fan	B W/O Fan	C % Time	D Zone Temp.	E ODB	F PMV
1	10.32	3.41	100	70.89	67.08	-0.23
2	10.32	3.41	100	70.29	66.40	-0.26
3	10.32	3.41	100	69.76	65.85	-0.28
4	10.32	3.41	100	69.32	65.44	-0.30
5	10.32	3.41	100	69.03	65.30	-0.35
6	41.03	34.12	100	69.34	65.57	-0.33
7	10.32	3.41	100	69.27	66.26	-0.34
8	10.32	3.41	100	69.71	67.49	-0.34
9	10.32	3.41	100	70.72	69.27	-0.27
10	10.32	3.41	100	71.91 <	71.33	-0.23
11	3.41	3.41	0	73.04 >	73.66	-0.13
12	3.41	3.41	0	73.61	75.85	-0.04
13	3.41	3.41	0	74.11	77.49	0.05
14	3.41	3.41	0	74.54	78.59	0.13
15	3.41	3.41	0	75.27	79.00	0.28
16	17.06	17.06	0	76.90 <	78.59	0.57
17	23.97	17.06	100	77.99 >	77.63	0.64
18	23.97	17.06	100	77.63	76.12	0.64
19	23.97	17.06	100	76.26	74.34	0.46
20	23.97	17.06	100	75.10	72.56	0.28
21	23.97	17.06	100	74.05	71.05	0.13
22	23.97	17.06	100	73.07	69.68	0.01
23	10.32	3.41	100	72.13	68.59	0.16
24	10.32	3.41	100	71.49	67.77	0.21

To enhance the existing system or to create a new control system, there should be interior and exterior thermostats. These thermostats would shut off fans when interior temperatures are lower than exterior temperatures, thus minimizing the flow of warm moist air into the zone during the hottest part of the day.

Shading Studies

Since the initial portion of this building analysis uncovered solar control problems, a more detailed study was conducted to analyze different methods of shading and to determine their effectiveness. These shading option simulations were performed on a model using the existing ventilation system controls and consisting of:

1. Vertical fins 3-ft wide, normal to the exterior wall, and extending from the base of each zone to the bottom of the overhang.

2. Shading screens installed on the exterior of the windows.[3]

3. Replacing glazing with Low-E insulated glass (simulated as a shading film).

[3] Information regarding the shading screens modeled in the simulations can be obtained from: KSI Shading Systems, Inc., Eastern Regions, 907 Murrah Forest Drive, North Augusta, SC 29814, tel. 1-800-528-9010.

Figures 15 and 16 show the effect of these various shading schemes on the mean air temperature and PMV for Zone 3.

As Figures 15 and 16 show, performance varies with the method employed to shade the window. The exterior shading screens function better than the other methods. The Low-E glazing out-performed the vertical shading fins. Although the vertical fins intercept most of the direct radiation falling upon the windows, there is still enough diffuse radiation entering through the windows so that the heat gain is still greater than with the Low-E glazing option. The Low-E glazing option reduces both direct and diffuse solar transmission.

The *ASHRAE Handbook of Fundamentals*[4] also contains information regarding this type of shading device. ASHRAE states that "The most effective way to reduce the load on fenestration is to intercept direct radiation from the sun before it reaches the glass. Windows fully shaded from the outside will have a solar heat gain reduction of as much as 80%." Since solar heat gain through the southwest windows is one of the primary problems with the building, shading may be an effective solution.

The criteria used to choose a shading system should be: life-cycle-cost, durability, effectiveness, and compatibility with the aesthetics of the building. Each option has advantages and disadvantages; selection should not focus on effectiveness alone. Evaluation of options is best left to individuals familiar with the base, its inhabitants, architectural character, etc.

Annual Simulations

As a conclusion to this study, the UEPH facility was modeled on an annual basis several ways. These runs used a Test Reference Year (TRY) ETAC weather file that ran from the first of August 1983 to the end of July 1984. TRY files consist of 8760 hours of climatic information for one year selected by eliminating extreme months in order of importance until only 1 year remains. These tapes do not necessarily represent the long term mean.

Infiltration

To account for infiltration throughout the year, the UEPH was simulated with three different levels of infiltration: from zero, to one-half, to one air change per hour (on a constant schedule). The increase in energy consumption was approximately 5 percent (2000 Btu/SF/YR) between the two extremes. Used throughout all of the annual simulations was an infiltration rate that reflected the bath exhaust fan rate placed on a residential lighting schedule. This in effect caused increased infiltration during occupied hours and decreased rates during daytime hours and is estimated to be a fair representation of what would actually occur.

BLAST Run Summary

Tables 3 and 4 detail how certain parameters were configured for the alternate runs. Discussion in later sections will cite these simulations. Rather than present all of the simulations conducted, only those most relevant to the study purposes are presented.

[4] *ASHRAE Handbook of Fundamentals* (American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. [ASHRAE], 1985), ch. 27.

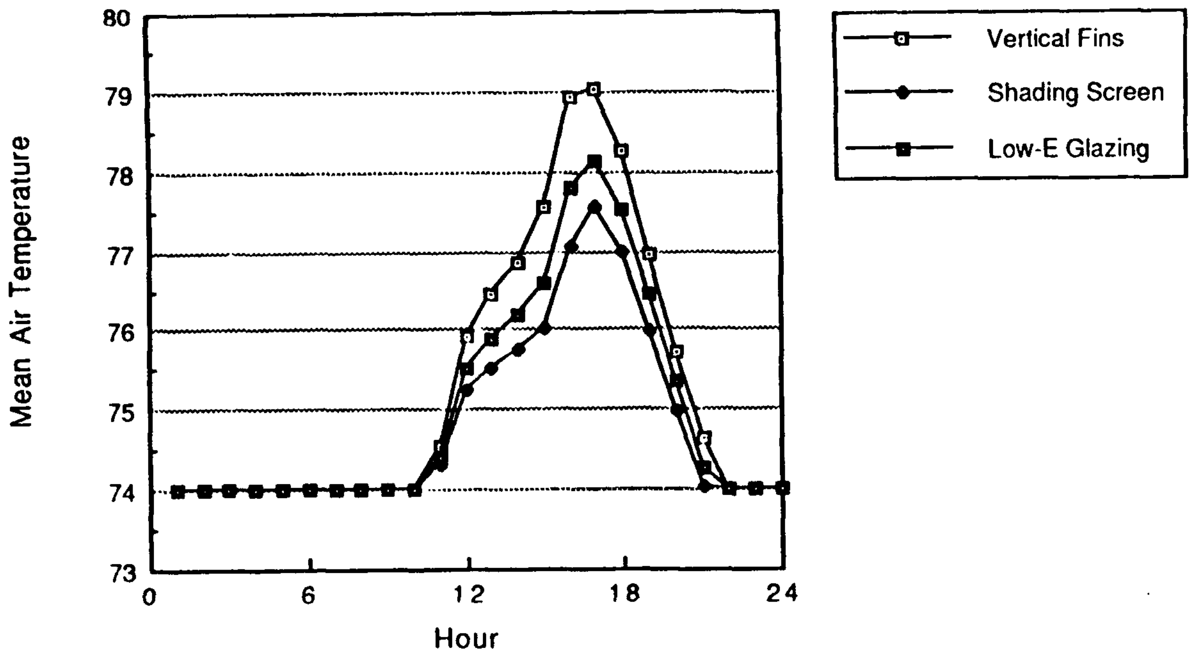


Figure 15. Mean Air Temperature With Various Shading Devices.

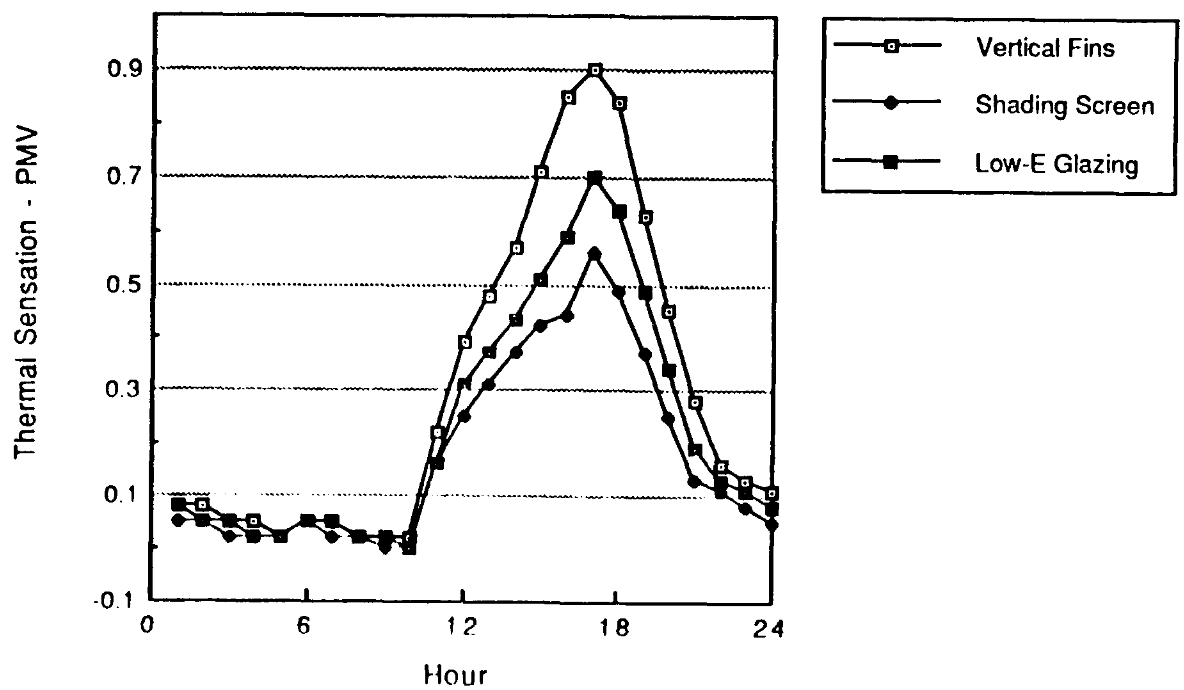


Figure 16. PMVs for Various Shading Devices.

Table 3
Infiltration Model — 2-Pipe Systems

File Name	Heat On	Heat Off	Heat Time	Ventilation Min Temp	Ventilation Del Temp	Ventilation Schedule On	Ventilation Schedule Off	System Schedule On	System Schedule Off	Heating Operation On	Heating Operation Off	Annual Energy Consumption Btu/sf/yr
2-Pipe Systems												
An25m4	68	73	0-24	74	0	0-24	-	-	0-24	0-24	-	1.54E+04
An25m2	63	64	0-24	65	0	0-24	-	-	0-24	0-24	-	1.72E+04
An25m3	63	64	0-24	74	0	0-24	-	-	0-24	0-24	-	1.53E+04
An25m5	68	73	0-24	69	0	0-24	-	-	0-24	0-24	-	1.66E+04
An25m6	68	73	0-24	69	0	18-6	6to18	-	0-24	0-24	-	1.52E+04

Table 4
Infiltration Model — 4-Pipe Systems

File Name	Controls Heat On	Controls Heat Off	Controls Cool Off	Controls Cool On	Controls Time	System Schedule On	System Schedule Off	Heating Operation On	Heating Operation Off	Cooling Operation On	Cooling Operation Off	Annual Energy Consumption Btu/sf/yr
4-Pipe Systems												
An100m5	68	73	77	78	0-24	0-24	-	0-24	-	0-24	-	4.68E+04
An100m1	68	73	77	78	0-24	18-6	6to18	0-24	-	0-24	-	4.17E+04
An100m6	68	73	77	78	0-24	-	0-24	0-24	-	0-24	-	3.46E+04
An100m3	68	73	77	78	0-24	-	0-24	18-6	6to18	18-6	6to18	2.55E+04

Existing Two-Pipe Fan-Coil Simulations - Ventilation = 74 °F

The initial annual simulations modeled the UEPH with its existing two-pipe fan-coil system and mechanical ventilation system. The purpose for modeling the existing conditions was to compare the model with later runs to see the energy and comfort implications of the various changes.

The two-pipe fan-coil system was modeled after the specifications indicated on the mechanical drawings, i.e., 8000 Btu and 320 CFM per fan-coil unit with 25 percent outside air. It was placed on a schedule that allowed it to operate throughout the year whenever interior temperatures dictated a need for heating.

The mechanical ventilation system was modeled with two different schedules: one that allowed the system to operate whenever the interior temperatures rose above 74 °F, regardless of time of day, and another that allowed the system to operate from 1800 to 0600 hours, again, whenever the interior temperatures rose above 74 °F. Both simulations shut off the fans whenever exterior temperatures exceeded interior temperatures. This method of operation eliminated the problem of overheating the

building during the hottest part of the day and is also a means of operation entirely possible with the unmodified existing system.

A baseline annual run was conducted to determine the yearly energy consumption for the existing system configuration. Following this, a separate simulation was conducted that encompassed a 4-month time period (July through October) for which hourly mean room air temperature, relative humidity, and PMV were determined. Since the existing system configuration used exterior air to ventilate the interior environment, the relative humidity in the interior of the building is assumed to be the same as the exterior ambient environment. This value of relative humidity was also the figure used to determine PMV values.

The great amount of data generated by these computer simulations limited observations to two zones, 3 and 7. Zone 3 experiences the worst summer conditions and is therefore of primary interest. Zone 7 is the coolest zone in the building.

Figures 17 to 22 show graphs of the MAT and PMV results for these two zones. Note that the patterns of the output for each zone are very similar; however, there is a distinct downwards shift in PMV and MAT from zone 3 to 7. Due to the subjective nature of thermal comfort, there is a necessity to establish objective upper and lower bounds of acceptability. ASHRAE's (proposed) threshold of acceptability was adopted at positive and negative point five (0.5) which corresponds to an environment that would be acceptable to 90 percent of the occupants (and unacceptable to 10 percent) (Figure 6). Use of the proposed threshold of 0.5 instead of 0.8, the threshold in the current ASHRAE Standard, leads to more conservative conclusions.

Figures 17 to 22 show graphed results from September through October. This time period was selected because it contains both some of the most extreme weather conditions encountered (in the ETAC weather file) and typical summer conditions. The two different ventilation set points used for the following graphs were 74 °F and 65 °F. Evident on the graph depicting mean air temperature is the radical difference in interior temperatures using two different set points for the ventilation motor thermostatic controls.

In zone three, when the thermostatic control set point was set at 74 °F, PMVs often exceeded 0.5, but when thermostatic controls were set at 65 °F, this limit is exceeded much less (Figures 17, 18, and 19). Moreover, at 65 °F, PMVs exceed the 0.5 limit primarily during unoccupied hours and are therefore not considered objectionable. Also, when thermostatic controls are lowered to 65 °F, nighttime interior conditions are still maintained within comfort limits; nighttime ventilation does not overcool occupants.

The results for zone seven are slightly different from zone three. Even with thermostatic controls set at 74 °F, conditions are much more acceptable (Figures 21 and 22). With the lowered thermostatic controls in zone seven, it is possible to overcool occupants with nighttime ventilation. This clearly shows that with readjusted thermostatic controls on the ventilation motors, it is possible to radically alter the thermal characteristics of the buildings interior.

A sort was conducted on the PMV data from zones 1, 3, and 7, to determine the amount of improvement with the lowered thermostatic controls. Apparent in Figure 23 is the marked increase in the number of hours during the 4-month time period that PMV values fall between -0.5 and +0.5. Remember that many of the hours PMVs fall outside the -0.5 to +0.5 range occur during unoccupied times. If a sort of acceptable PMVs were conducted on only occupied hours, the percent of time the environment is considered acceptable would increase.

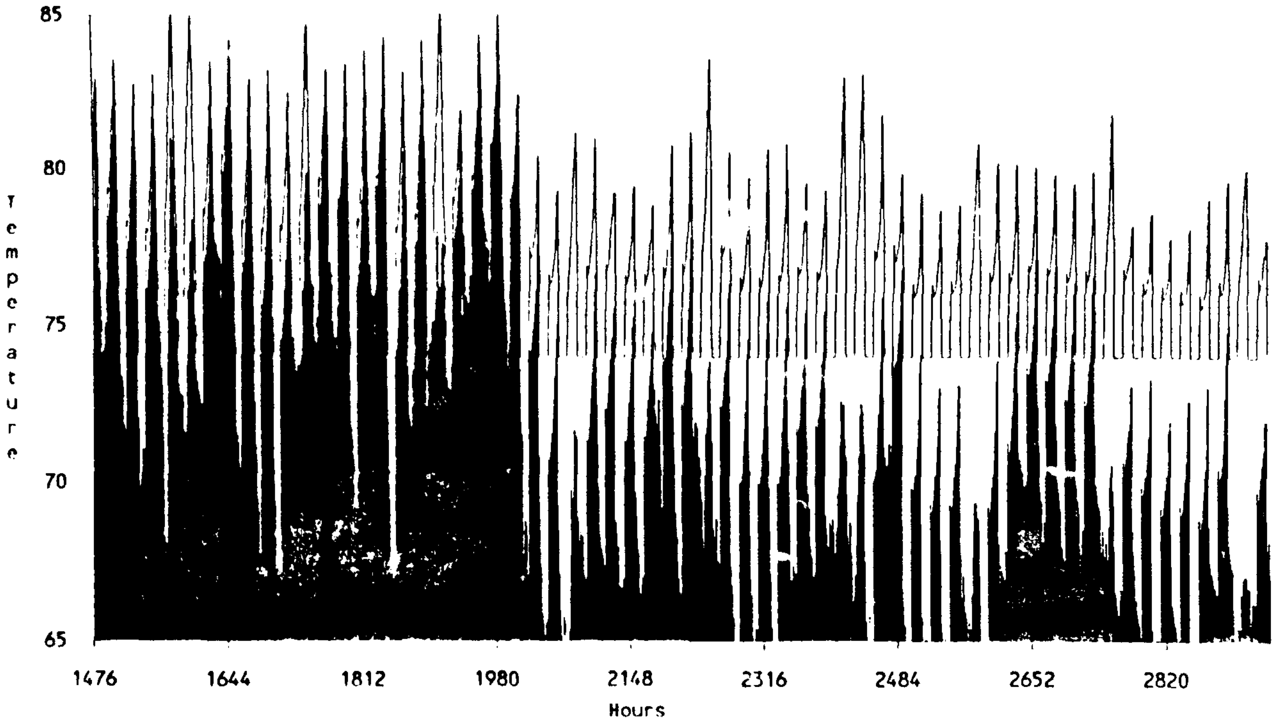


Figure 17. Mean Air Temperature Using Two Different Ventilation Thermostat Set Points (Zone 3).

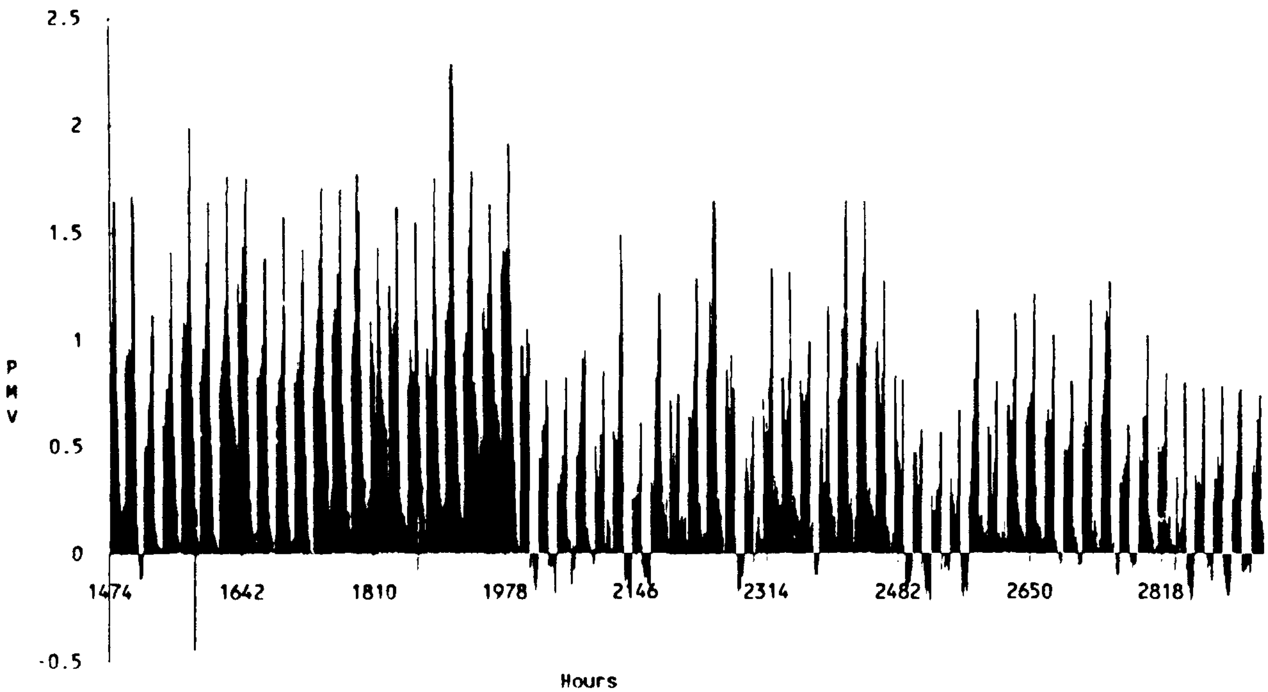


Figure 18. Zone 3 PMV (Ventilation Thermostat Set Point = 74 °F).

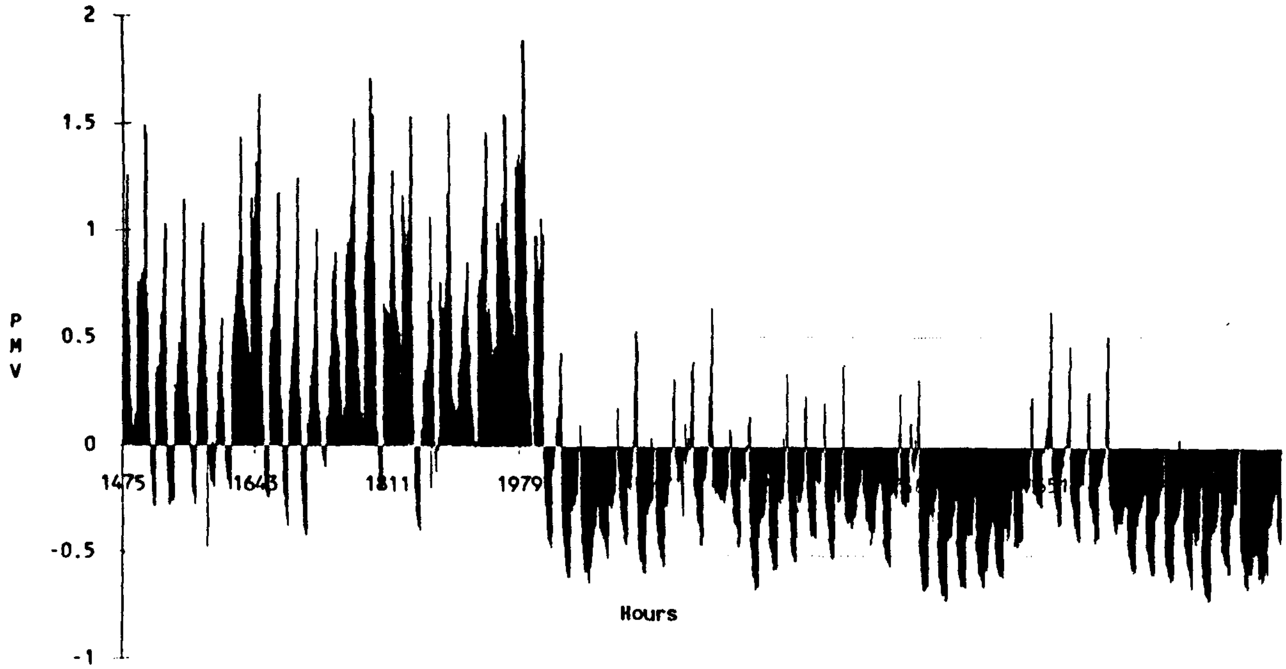


Figure 19. Zone 3 PMV (Ventilation Thermostat Set Point = 65 °F).

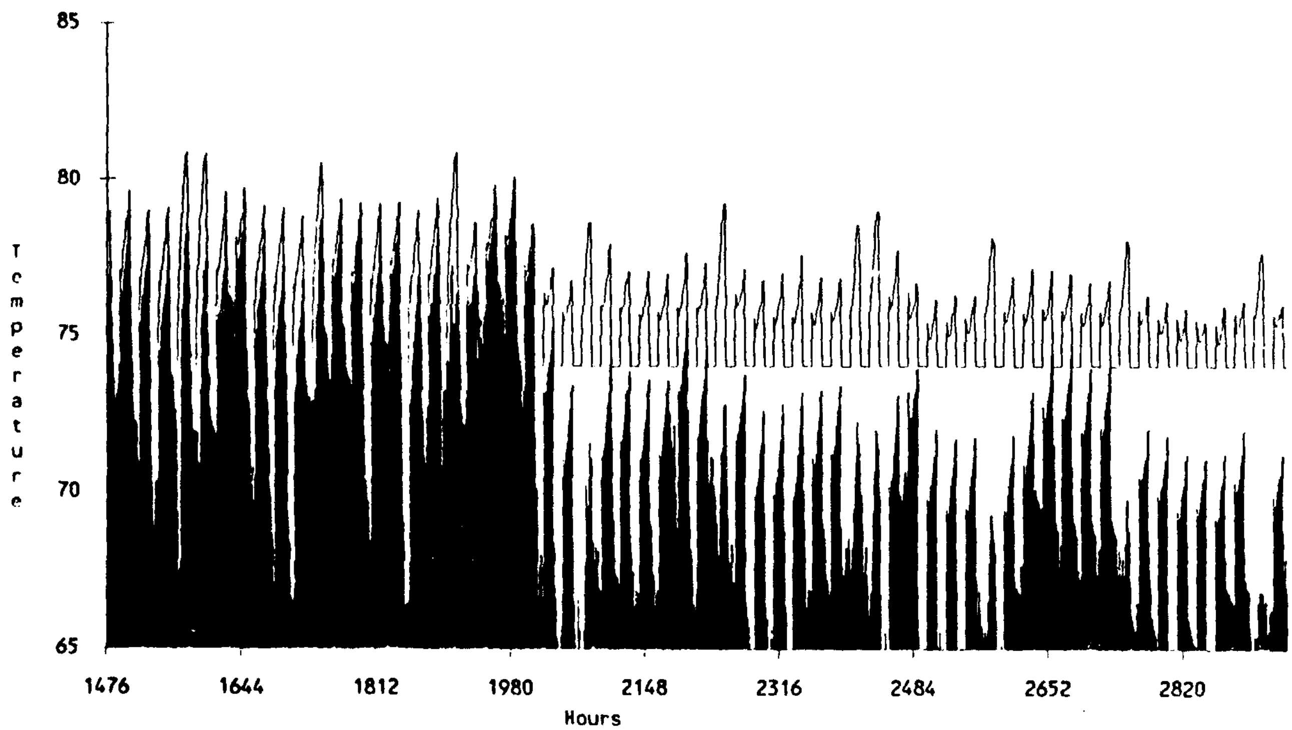


Figure 20. Zone 7 Mean Air Temperature Using Two Different Ventilation Thermostat Set Points.

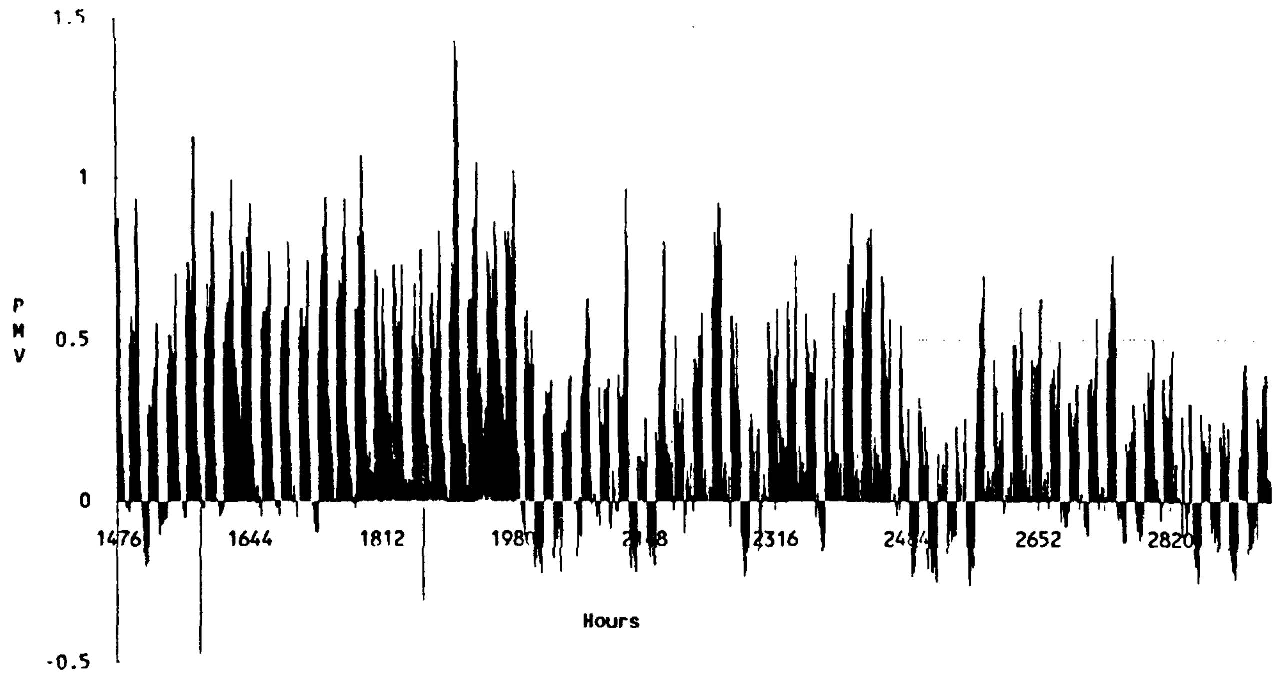


Figure 21. Zone 7 PMV (Ventilation Thermostat Set Point = 74 °F).

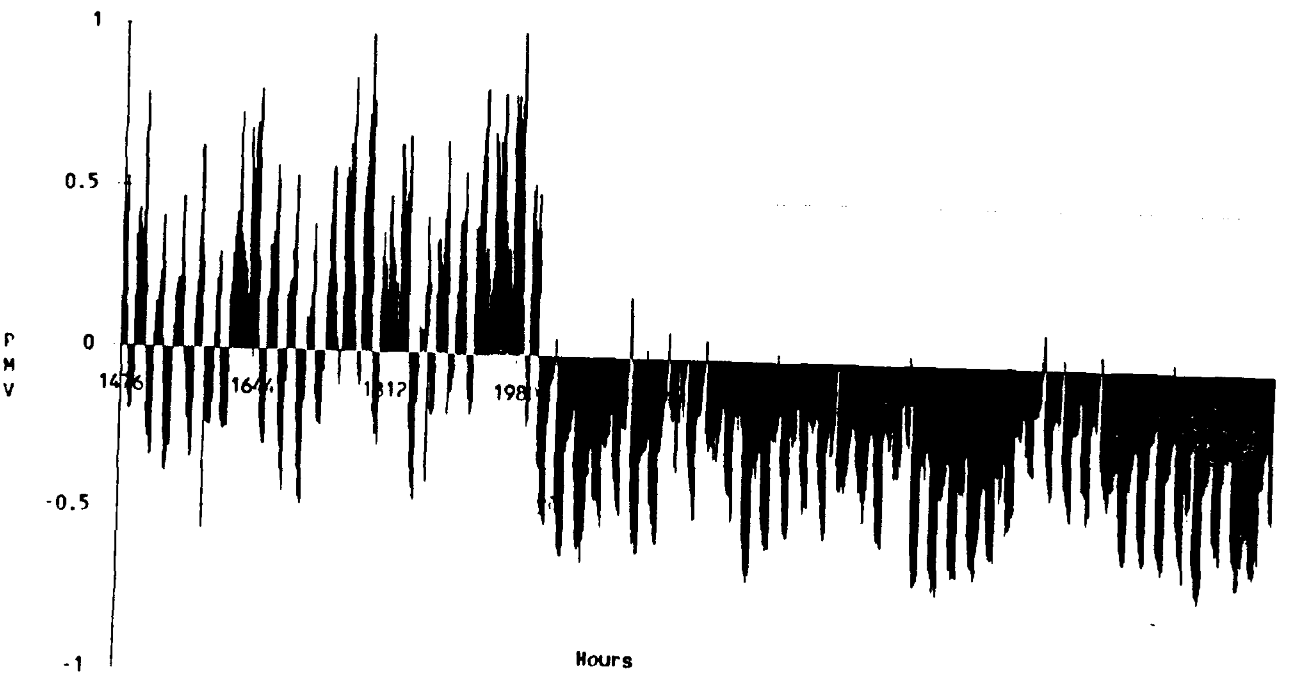


Figure 22. Zone 7 PMV (Ventilation Thermostat Set Point = 65 °F).

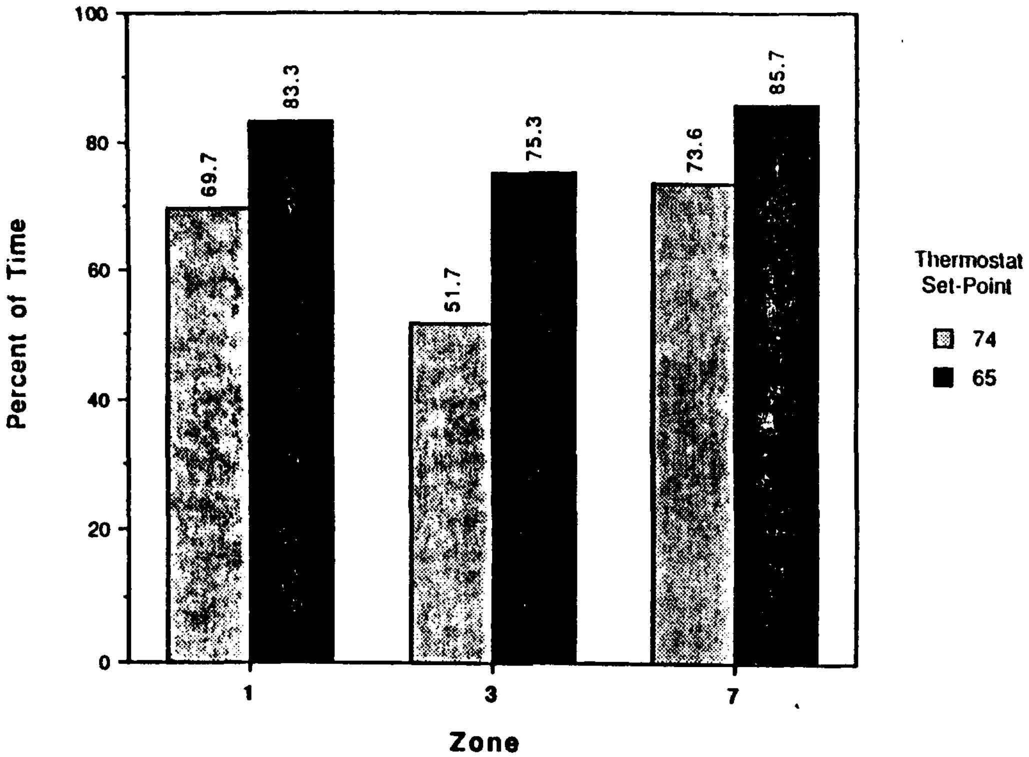


Figure 23. Period of Time PMV Falls Between -0.50 and +0.50 July Through October.

The importance of thermostatic set points was further studied with different ventilation schedules to determine cycling time influence on interior temperatures. To study this, a 6-day time period was selected that contained the worst conditions encountered during September. Fans were cycled for different time periods at different set points and the interior temperatures were graphed (Figure 24).

Figure 24 reveals some interesting trends. Even when exterior dry bulb temperatures fall well below 74 °F, zone 3 interior temperatures remain at or above 74 °F. Clearly, the longer the ventilation fans cycle, the cooler the interior environment. However, the benefit is marginal when exterior temperatures rise above 74 °F. What is of greatest interest on this graph are the high interior air temperatures on 18 September. Although exterior air temperatures on the 18th barely rise above 75 °F, the interior air temperatures are higher than the day before when exterior temperatures rose above 80 °F. This occurs for two reasons:

1. During the final hours of the 17th and early morning hours of the 18th, exterior temperatures did not drop enough for nighttime ventilation to be beneficial.

2. The structure shows a thermal lag, i.e., the previous day's high temperatures combine with the high nighttime temperatures to manifest themselves inside the building well after they occur. This point is also seen with the interior temperatures on the 19th. The lower exterior temperatures of the day and night of the 18th allow the ventilation to cool the structure so that during the day on the 19th, interior temperatures remain lower than the day before.

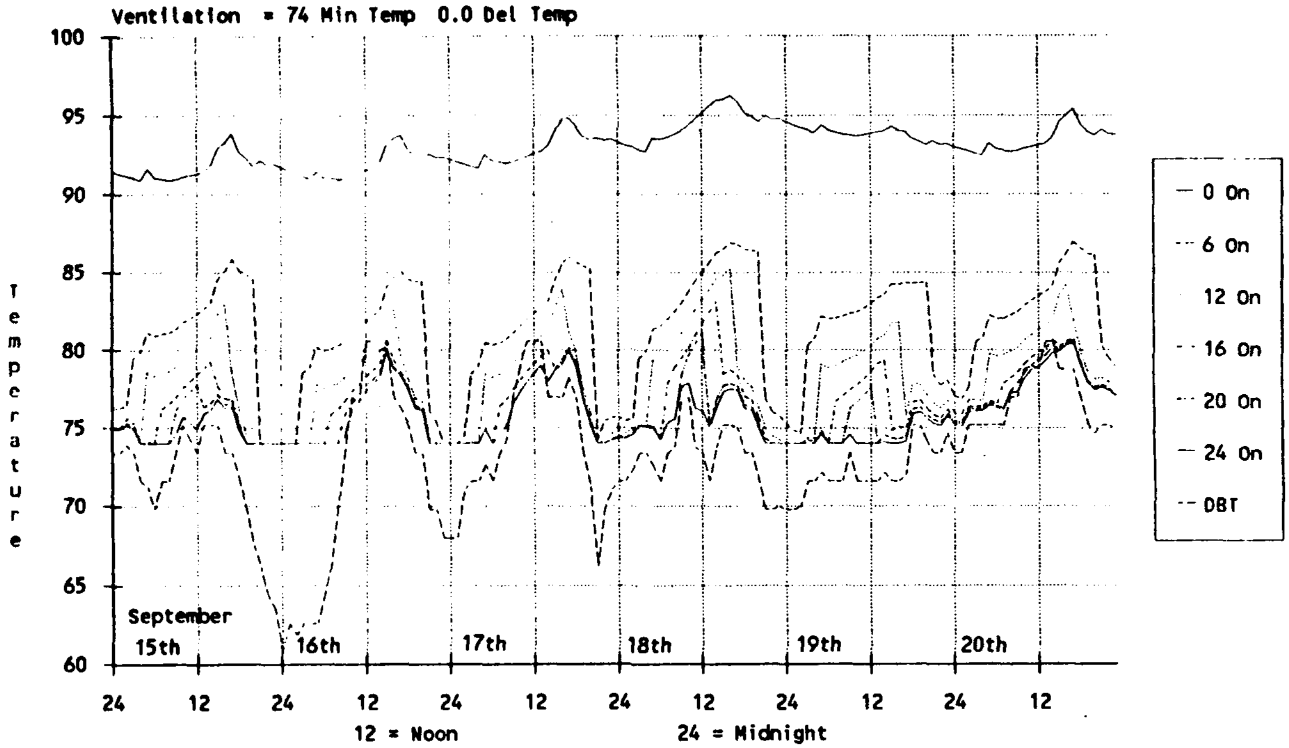


Figure 24. Zone 3 MAT With Various Ventilation Schedules (74 °F).

A final point of interest on this graph is the significance of ventilation. Temperatures rise to intolerable highs when the ventilation fans do not cycle. Interior temperatures remain above 90 °F during the entire 6 days. However, even when the fans are only cycled 6 hours during the late evening/early morning hours, the interior temperature drop is significant.

The BLAST models lead to one distinct conclusion: if no future modifications are made to the ventilation system and in-duct thermostats in existence remain, the best interior environmental conditions occur with the fans running constantly.

The one objection to constant electrical ventilation would be the increased electrical consumption. Annual energy consumption for the simulations with existing controls was 15,400 Btu/SF/YR. This was with the ventilation scheduled to operate whenever interior temperatures rose above 74 °F and full heating at 68 °F.

Existing Two-Pipe Fan-Coil Simulations - Ventilation = 65 °F

The following simulations all used a modified ventilation statement in which the in-duct thermostat set point was lowered to 65 °F. Now, instead of the ventilation motor attempting to cool the interior to 74 °F as before, it attempted to cool the interior to 65 °F. With this modification, the bedroom temperature control statement needed to be modified. BLAST does not allow mechanical ventilation to cool the

interior below temperatures requiring heating, so interior thermostatic heating controls were set so that coils would be fully on at 62 °F and off at 64 °F. With this configuration, there was very little heating demand on the system.

Figure 25 shows a graph plotting Zone 3 temperatures for the same 6-day time period as before, but with the lowered in-duct thermostat. On nights when temperatures drop substantially below daytime temperatures, and the ventilation fans are allowed to cycle at night, the following day's interior temperatures are reduced (cf. the temperatures on the night of the 15th and throughout the 16th). When the mass of the building is allowed to cool at night, its ability to absorb more heat throughout the next day is increased thus resulting in an improved interior environment. The reader should be reminded that this time period being observed is the warmest encountered in Zone 3 for a 4-month time period. Other zone's temperatures are generally lower than these. Therefore, if Zone 3's interior temperatures can be maintained through mechanical ventilation, the other zone's temperatures can undoubtedly be managed through ventilation also.

Energy consumption for this mechanical configuration is naturally greater than when in-duct thermostats were set at 74 °F. However, this increase can be controlled through strategic fan operation scheduling. Notice on the graph how even when fans are scheduled to only run for 6 hours of the night, interior temperatures are reduced on the following day (e.g., on the 16th). Rather than cycle the fans for 6 hours during the daytime when temperatures are hot and the spaces are unoccupied, the fans can cycle during the night so that occupants can benefit from the increased air motion, and from the reduced thermal capacity of the structure.

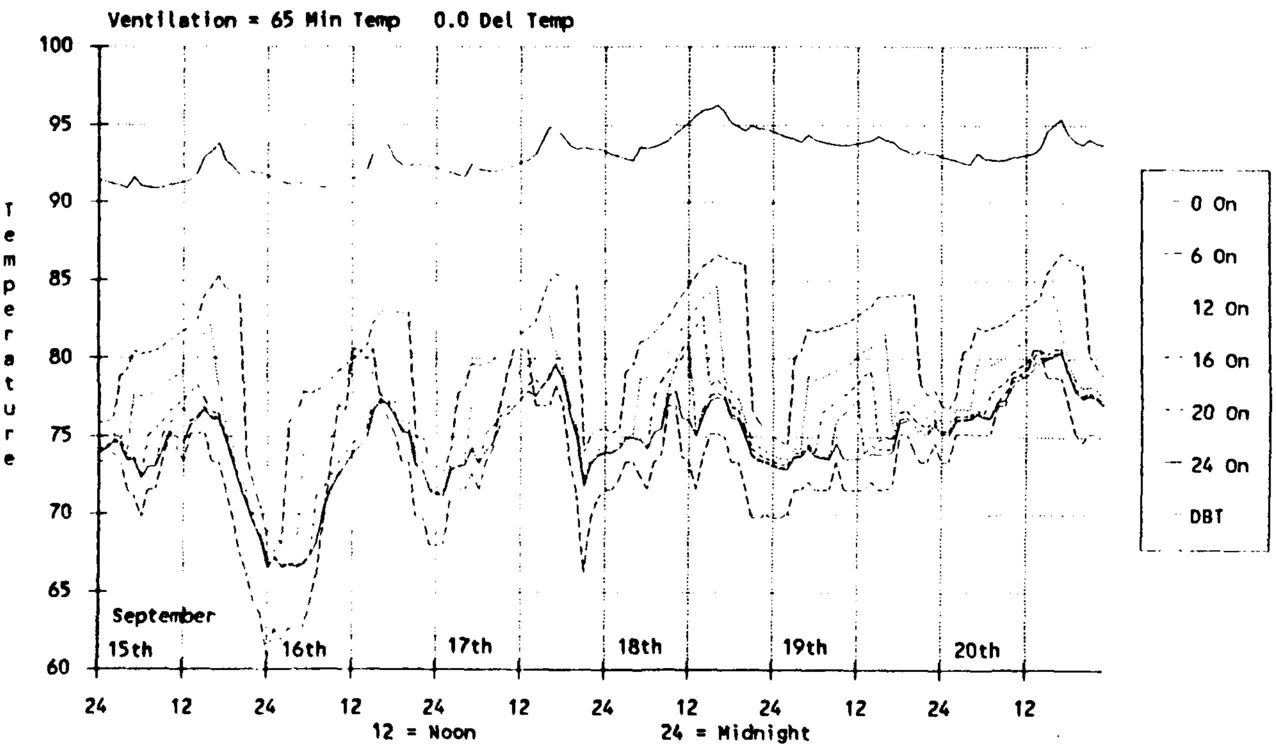


Figure 25. Zone 3 MAT With Various Ventilation Schedules (65 °F).

Annual energy consumption for the simulation with ventilation cooling set to 65 °F was 17,200 Btu/SF/YR with the ventilation schedule set to operate whenever interior temperatures exceeded 65 °F. Since heating set points had to be lowered for this simulation to operate, one of the previous decks with ventilation set at 74 °F was rerun with the same lowered set points to compare energy consumption. That particular run yielded an energy consumption of 15,300 Btu/SF/YR. The difference between the two runs (1900 Btu/SF/YR) is attributable to the increased cycling of the ventilation motors.

Four-Pipe Fan-Coil Simulations

To conclude this study, a four-pipe fan-coil system was simulated instead of the existing two-pipe system. This system would allow both heating and cooling to be provided as required by each zone, and would be the most flexible and precise of any of the systems simulated. Control of the interior environment to this degree, however, carries with it an energy penalty.

Results indicate that during the winter months the east zones on the first floor demand both heating and cooling, depending on climatic conditions. However, the predominant demand is for chilled water. This being the case, both heating and cooling are necessary and are made available. If only chilled water were provided during certain times of the year, then the building would require modifications (such as adding baseboard heaters) to accommodate zones requiring heating.

Because interior temperatures with this system are maintained within strict limits, it is not necessary to graph their results. All PMV values fall within an acceptable comfort range. Of prime concern with these simulations is the energy consumption for the four-pipe system.

The initial four-pipe simulation indicated an energy usage so high that subsequent models placed the system and coils on various schedules to observe energy consumption and interior temperatures. Four of these simulations will be briefly discussed:

1. The initial four-pipe simulation placed all systems and coils on a constant-on schedule. This configuration maintained interior temperatures between 68 °F and 78 °F at all times. Thus, no matter what time occupants were in a room, they would be comfortable, or would be able to adjust interior conditions to their own liking. This is a rather simple means of operation since everything is simply left on at all times. Annual energy consumption was 46,810 Btu/SF/YR, and would not satisfy DOD Annual Energy Target (AET) design criteria (40,000 Btu/SF/YR for this building type in this weather region).

2. The second simulation left the coils on throughout the day, but placed the system operating schedule on from 1800 to 0600 hours, and off from 0600 to 1800 hours. Although no mechanically assisted ventilation is achieved from 0600 to 1800 hours, temperatures are maintained as before. This method of operation would require the fan-coil unit to be operated by a timer. Energy consumption dropped to 41,680 Btu/SF/YR. The energy difference between this configuration and the previous simulation resulted from fan motor loads due to ventilation.

3. The third simulation placed all systems and coils on a schedule that turned them on from 1800 to 0600 hours, and off from 0600 to 1800 hours. For this configuration, both fan-coil units and hot and chilled water circulating pumps would need to be operated by a timer. Similar to scheme two, no mechanically assisted ventilation is achieved from 0600 to 1800 hours. Energy consumption dropped off considerably (31,710 Btu/SF/YR), but at the cost of high interior temperatures at times when the system was scheduled off. Zone-3 temperatures exceeded 89 °F, more or less rendering this operational scheme unacceptable.

4. The fourth scheme placed the system on a constant-off schedule and placed the coils on a constant-on schedule. This scheme allows any zone to be heated or cooled as required, i.e., the system operates only when called upon. Thus, the fan-coil unit is operated by the occupant, but hot and chilled water are available upon demand. The energy consumption for this particular configuration was 34,600 Btu/SF/YR, approximately twice that of the schemes using a two-pipe system with mechanical ventilation.

For the four-pipe fan-coil mechanical scheme to operate and offer distinct improvements over the existing environment, it would need to be configured as in scheme four. To schedule it to be operational throughout only a part of the day would create an environment no better than existing. Since the Azores environment has only 621 cooling degree days, and the building type does not require strict humidity control, it would be very difficult to justify the energy and expense of a four-pipe mechanical system.

Comfort Modeling and Associated Energy Consumption

New BLAST Comfort Reports

This project provided an ideal opportunity for application of the new BLAST comfort models. To enhance the usefulness of the BLAST comfort modeling capabilities, a new report and associated sorting program were developed. The new report is invoked by specifying the name of the comfort model desired (i.e., Pierce, Fanger, or KSU), and by adding the number 123 to the reports statement in the input deck. For example, the following statement would generate reports using the Fanger and Pierce models: Reports (Fanger,Pierce,123).

This statement can currently not be used with design day runs and must be used with weather files. Figure 26 shows output for the UEPH facility, but only depicts 2 hours worth of data for 18 zones.

Since the output is reported on a zone-by-zone basis for each hour of the day, the output file can quickly become very large.

To process this data into a more usable format, a special sort program was written. For each zone, this program counts the number of occupied and unoccupied hours that fall within a certain comfort (PMV), temperature, and relative humidity range. It also gives the total number of hours and maximum/minimum value in each bin so that percentage of time and extremes within each bin can be calculated. Figure 27 shows an example of the output from this program.

This report helps to determine if the environment within a building would be considered thermally acceptable or not. PMV values during occupied periods below negative one (-1) would indicate that the mechanical system is providing too little heat (assuming all other modeling parameters are specified correctly). PMV values above one (+1) indicate insufficient cooling.

These new reporting capabilities greatly extend the modeling capabilities of BLAST and provide an added dimension to building analysis. Now, rather than only focus on loads, BLAST can actually calculate human physiological response to surrounding environmental parameters. In many respects this is a much more comprehensive analysis of the interior environment since the comfort algorithm takes into account more than just loads within a space. Air and radiant temperatures, humidity, and air velocity are all accounted for as are clothing levels and metabolic rates. Simply because loads within a space are met does not imply that an individual will be comfortable. These new features in BLAST allow a more realistic and comprehensive assessment of the interior environment.

Comfort Results From Reports

Three of the previously developed UEPH input decks were rerun using the new BLAST comfort reporting features. Three different ventilation schedules were modeled using the standard deck with the ventilation motor set at 74 °F:

1. Day Ventilation (0600-1800 on, 1800-0600 off)
2. Night Ventilation (0600-1800 off, 1800-0600 on)
3. Constant Ventilation (0000-2400 on).

These decks were run from the first of July through the end of October (4 months or 2952 hours). Of these 2952 hours, 1728 were specified as being occupied hours. Figure 27 depicts the results for Zone 3 or these occupied hours.

When the ventilation system is specified to operate on demand throughout the day, comfort levels are greatest. Following this is the nighttime scheme and then the daytime scheme. Clearly visible is that the daytime scheme is a poor system operation alternative. Its peak is in an unacceptably hot comfort bin.

Energy Consumption

Although analyzing the physiological response of humans to the interior environment is an entirely new way to analyze a buildings operational success, it would be incomplete without also observing the energy implications of each alternative. Energy consumption was recorded for the same three models used above and an additional three models where the ventilation set point temperature was reset to 65 °F. The results are presented in Figure 28.

BLAST-FORMAT 3.0 "Thermal Comfort Reports Data File
NUMBER OF ZONES = 18
NUMBER OF HOURS = 2952
USER ZONE NUMBERS:
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18
VARIABLES ARE:
DATE = DATE IN MM/DD FORMAT
TIME = CLOCK TIME
UZN = USER ZONE NUMBER
MAT = MEAN AIR TEMPERATURE
RH = RELATIVE HUMIDITY (PERCENT)
P-PMV = PIERCE PREDICTED MEAN VOTE - SET
P-TSI = PIERCE THERMAL SENSATION INDEX - SET
P-PMVet = PIERCE PREDICTED MEAN VOTE - ET
P-TSIet = PIERCE THERMAL SENSATION INDEX - ET
F-PMV = FANGER PREDICTED MEAN VOTE
K-TSV = KANSAS STATE THERMAL SENSATION VOTE

** NOTE: VALUES OF -99 INDICATE THAT A PARTICULAR THERMAL COMFORT REPORT WAS NOT TURNED ON.

DATE/TIME	UZN	MAT	RH (%)	Occ	P-PMV	P-TSI	P-PMVet	P-TSIet	F-PMV	K-TSV
7 1 1	1	74.00	100.	T	0.25	-00.00	0.54	-00.00	-99.00	-99.00
7 1 1	2	74.00	100.	T	0.34	0.07	0.63	0.08	-99.00	-99.00
7 1 1	3	74.00	100.	T	0.31	0.05	0.60	0.06	-99.00	-99.00
7 1 1	4	74.00	100.	T	0.25	-00.00	0.54	-00.00	-99.00	-99.00
7 1 1	5	74.00	100.	T	0.31	0.04	0.60	0.06	-99.00	-99.00
7 1 1	6	74.00	100.	T	0.31	0.03	0.60	0.04	-99.00	-99.00
7 1 1	7	74.00	100.	T	0.25	-00.00	0.54	-00.00	-99.00	-99.00
7 1 1	8	74.00	100.	T	0.34	0.06	0.63	0.07	-99.00	-99.00
7 1 1	9	74.00	100.	T	0.31	0.03	0.60	0.04	-99.00	-99.00
7 1 1	10	73.45	83.	F	-0.07	-0.02	0.13	-0.02	-99.00	-99.00
7 1 1	11	74.56	83.	F	0.13	-0.01	0.33	-0.01	-99.00	-99.00
7 1 1	12	75.06	83.	F	0.22	0.03	0.42	0.04	-99.00	-99.00
7 1 1	13	82.36	83.	F	1.69	1.33	1.84	1.32	-99.00	-99.00
7 1 1	14	85.45	83.	F	2.40	1.86	2.53	2.07	-99.00	-99.00
7 1 1	15	86.18	83.	F	2.55	1.97	2.71	2.27	-99.00	-99.00
7 1 1	16	73.34	83.	F	-0.07	-0.02	0.10	-0.02	-99.00	-99.00
7 1 1	17	73.07	83.	F	-0.13	-0.03	0.07	-0.03	-99.00	-99.00
7 1 1	18	73.59	83.	F	-0.04	-0.02	0.16	-0.02	-99.00	-99.00
7 1 2	1	74.00	94.	T	0.15	-0.01	0.44	-0.01	-99.00	-99.00
7 1 2	2	74.00	94.	T	0.23	0.01	0.52	0.03	-99.00	-99.00
7 1 2	3	74.00	94.	T	0.20	-00.00	0.49	-00.00	-99.00	-99.00
7 1 2	4	74.00	94.	T	0.15	-0.01	0.44	-0.01	-99.00	-99.00
7 1 2	5	74.00	94.	T	0.20	-00.00	0.52	-00.00	-99.00	-99.00
7 1 2	6	74.00	94.	T	0.20	-00.00	0.49	-00.00	-99.00	-99.00
7 1 2	7	74.00	94.	T	0.15	-0.01	0.44	-0.01	-99.00	-99.00
7 1 2	8	74.00	94.	T	0.23	0.00	0.52	0.00	-99.00	-99.00
7 1 2	9	74.00	94.	T	0.20	-00.00	0.49	-00.00	-99.00	-99.00
7 1 2	10	73.41	83.	F	-0.07	-0.02	0.13	-0.02	-99.00	-99.00
7 1 2	11	74.54	83.	F	0.13	-0.01	0.33	-0.01	-99.00	-99.00
7 1 2	12	75.04	83.	F	0.22	0.03	0.42	0.04	-99.00	-99.00
7 1 2	13	81.86	83.	F	1.57	1.25	1.75	1.21	-99.00	-99.00
7 1 2	14	85.08	83.	F	2.31	1.80	2.44	1.97	-99.00	-99.00
7 1 2	15	85.72	83.	F	2.43	1.90	2.59	2.14	-99.00	-99.00
7 1 2	16	73.23	83.	F	-0.10	-0.03	0.10	-0.03	-99.00	-99.00
7 1 2	17	72.96	83.	F	-0.15	-0.03	0.04	-0.03	-99.00	-99.00
7 1 2	18	73.01	83.	F	-0.13	-0.03	0.04	-0.03	-99.00	-99.00

Figure 26. Sample BLAST Comfort Report.

Reporting for Pierce 2 Node SET*
Using Zones 1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18
Weather Period Jul 1 -- Oct 31

Occupied Bins (Hours)

Zone	<-3	-3<>-2	-2<>-1	-1<>-.5	-.5<>.5	.5<>1	1<>2	2<>3	>3
1					1456	225	47		
2					1360	261	107		
3					1318	259	145	6	
4					1499	201	28		
5					1442	231	55		
6					1403	224	101		
7					1501	199	28		
8					1414	238	76		
9					1392	235	101		
10									
11									
12									
13							572	373	
14							79	765	101
15							87	607	251
16									
17									
18									

Unoccupied Bins (Hours)

Zone	<-3	-3<>-2	-2<>-1	-1<>-.5	-.5<>.5	.5<>1	1<>2	2<>3	>3
1					810	391	23		
2					327	769	128		
3					305	736	183		
4					868	353	3		
5					477	693	54		
6					413	707	104		
7					877	344	3		
8					385	767	72		
9					445	676	103		
10					2952				
11					1855	1097			
12					1384	1559	9		
13						302	1688	17	
14							1135	872	
15							838	1150	19
16					1931	1001	20		
17					2541	411			
18				147	1331	569	570	262	73

Totals Bins (Hours)

Zone	<-3	-3<>-2	-2<>-1	-1<>-.5	-.5<>.5	.5<>1	1<>2	2<>3	>3
1					2266	616	70		
2					1687	1030	235		
3					1623	995	328	6	
4					2367	554	31		
5					1919	924	109		
6					1816	931	205		
7					2378	543	31		
8					1799	1005	148		
9					1837	911	204		
10					2952				
11					1855	1097			
12					1384	1559	9		
13						302	2260	390	
14							1214	1637	101
15							925	1757	270
16					1931	1001	20		
17					2541	411			
18				147	1331	569	570	262	73

Figure 27. Sample Sort Program Output.

Occupied Temperatures

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	74/ 78	76/ 82	77/ 82	***/***	***/***
2	***/***	***/***	***/***	***/***	74/ 78	75/ 82	78/ 84	***/***	***/***
3	***/***	***/***	***/***	***/***	74/ 78	74/ 82	78/ 85	82/ 85	***/***
4	***/***	***/***	***/***	***/***	74/ 78	76/ 81	78/ 81	***/***	***/***
5	***/***	***/***	***/***	***/***	74/ 78	75/ 82	78/ 82	***/***	***/***
6	***/***	***/***	***/***	***/***	74/ 78	76/ 82	78/ 84	***/***	***/***
7	***/***	***/***	***/***	***/***	74/ 78	76/ 81	78/ 81	***/***	***/***
8	***/***	***/***	***/***	***/***	74/ 79	75/ 82	78/ 83	***/***	***/***
9	***/***	***/***	***/***	***/***	74/ 78	76/ 82	78/ 84	***/***	***/***
10	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	***/***	80/ 84	84/ 87	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	82/ 84	84/ 88	88/ 90
15	***/***	***/***	***/***	***/***	***/***	***/***	82/ 84	84/ 88	88/ 91
16	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
17	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
18	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***

Unoccupied Temperatures

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	75/ 79	75/ 81	78/ 82	***/***	***/***
2	***/***	***/***	***/***	***/***	75/ 80	76/ 81	78/ 83	***/***	***/***
3	***/***	***/***	***/***	***/***	75/ 80	76/ 82	78/ 84	***/***	***/***
4	***/***	***/***	***/***	***/***	74/ 79	75/ 80	78/ 78	***/***	***/***
5	***/***	***/***	***/***	***/***	75/ 80	76/ 81	78/ 82	***/***	***/***
6	***/***	***/***	***/***	***/***	75/ 80	76/ 81	78/ 83	***/***	***/***
7	***/***	***/***	***/***	***/***	74/ 79	75/ 80	78/ 78	***/***	***/***
8	***/***	***/***	***/***	***/***	75/ 80	76/ 81	78/ 82	***/***	***/***
9	***/***	***/***	***/***	***/***	75/ 80	76/ 81	78/ 83	***/***	***/***
10	***/***	***/***	***/***	***/***	71/ 75	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	72/ 76	76/ 78	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	72/ 76	76/ 79	79/ 79	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	78/ 79	79/ 84	84/ 85	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	80/ 84	84/ 88	***/***
15	***/***	***/***	***/***	***/***	***/***	***/***	80/ 84	84/ 88	88/ 89
16	***/***	***/***	***/***	***/***	69/ 76	76/ 79	79/ 79	***/***	***/***
17	***/***	***/***	***/***	***/***	69/ 76	76/ 78	***/***	***/***	***/***
18	***/***	***/***	***/***	63/ 67	67/ 77	76/ 79	79/ 84	84/ 88	88/ 97

Temperature Totals

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	74/ 79	75/ 82	77/ 82	***/***	***/***
2	***/***	***/***	***/***	***/***	74/ 80	75/ 82	78/ 84	***/***	***/***
3	***/***	***/***	***/***	***/***	74/ 80	74/ 82	78/ 85	82/ 85	***/***
4	***/***	***/***	***/***	***/***	74/ 79	75/ 81	78/ 81	***/***	***/***
5	***/***	***/***	***/***	***/***	74/ 80	75/ 82	78/ 82	***/***	***/***
6	***/***	***/***	***/***	***/***	74/ 80	76/ 82	78/ 84	***/***	***/***
7	***/***	***/***	***/***	***/***	74/ 79	75/ 81	78/ 81	***/***	***/***
8	***/***	***/***	***/***	***/***	74/ 80	75/ 82	78/ 83	***/***	***/***
9	***/***	***/***	***/***	***/***	74/ 80	76/ 82	78/ 84	***/***	***/***
10	***/***	***/***	***/***	***/***	71/ 75	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	72/ 76	76/ 78	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	72/ 76	76/ 79	79/ 79	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	78/ 79	79/ 84	84/ 87	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	80/ 84	84/ 88	88/ 90
15	***/***	***/***	***/***	***/***	***/***	***/***	80/ 84	84/ 88	88/ 91
16	***/***	***/***	***/***	***/***	69/ 76	76/ 79	79/ 79	***/***	***/***
17	***/***	***/***	***/***	***/***	69/ 76	76/ 78	***/***	***/***	***/***
18	***/***	***/***	***/***	63/ 67	67/ 77	76/ 79	79/ 84	84/ 88	88/ 97

Figure 27. (Cont'd.)

Occupied Relative Humidity

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	13/100	57/ 96	65/100	***/***	***/***
2	***/***	***/***	***/***	***/***	13/100	57/ 94	57/100	***/***	***/***
3	***/***	***/***	***/***	***/***	13/100	57/ 96	57/100	78/ 94	***/***
4	***/***	***/***	***/***	***/***	13/100	57/100	69/100	***/***	***/***
5	***/***	***/***	***/***	***/***	13/100	57/ 96	65/100	***/***	***/***
6	***/***	***/***	***/***	***/***	13/100	57/ 96	57/100	***/***	***/***
7	***/***	***/***	***/***	***/***	13/100	57/100	69/100	***/***	***/***
8	***/***	***/***	***/***	***/***	13/100	57/ 96	62/100	***/***	***/***
9	***/***	***/***	***/***	***/***	13/100	57/ 96	57/100	***/***	***/***
10	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83
15	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83
16	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
17	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***
18	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***	***/***

Unoccupied Relative Humidity

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	46/ 94	56/100	69/100	***/***	***/***
2	***/***	***/***	***/***	***/***	46/ 89	53/100	65/100	***/***	***/***
3	***/***	***/***	***/***	***/***	46/ 89	46/100	61/100	***/***	***/***
4	***/***	***/***	***/***	***/***	46/100	62/100	94/100	***/***	***/***
5	***/***	***/***	***/***	***/***	46/ 94	56/100	65/100	***/***	***/***
6	***/***	***/***	***/***	***/***	46/ 94	53/100	65/100	***/***	***/***
7	***/***	***/***	***/***	***/***	46/100	62/100	94/100	***/***	***/***
8	***/***	***/***	***/***	***/***	46/ 89	53/100	65/100	***/***	***/***
9	***/***	***/***	***/***	***/***	46/ 89	53/100	65/100	***/***	***/***
10	***/***	***/***	***/***	***/***	83/ 83	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***
15	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83
16	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***	***/***
17	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***	***/***	***/***
18	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	83/ 83	83/ 83	83/ 83

Relative Humidity Totals

Zone	<-3 Min/Max	-3<>-2 Min/Max	-2<>-1 Min/Max	-1<>-.5 Min/Max	-.5<>.5 Min/Max	.5<>1 Min/Max	1<>2 Min/Max	2<>3 Min/Max	>3 Min/Max
1	***/***	***/***	***/***	***/***	13/100	56/100	65/100	***/***	***/***
2	***/***	***/***	***/***	***/***	13/100	53/100	57/100	***/***	***/***
3	***/***	***/***	***/***	***/***	13/100	46/100	57/100	78/ 94	***/***
4	***/***	***/***	***/***	***/***	13/100	57/100	69/100	***/***	***/***
5	***/***	***/***	***/***	***/***	13/100	56/100	65/100	***/***	***/***
6	***/***	***/***	***/***	***/***	13/100	53/100	57/100	***/***	***/***
7	***/***	***/***	***/***	***/***	13/100	57/100	69/100	***/***	***/***
8	***/***	***/***	***/***	***/***	13/100	53/100	62/100	***/***	***/***
9	***/***	***/***	***/***	***/***	13/100	53/100	57/100	***/***	***/***
10	***/***	***/***	***/***	***/***	83/ 83	***/***	***/***	***/***	***/***
11	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***	***/***	***/***
12	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***	***/***
13	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***
14	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83
15	***/***	***/***	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83
16	***/***	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	***/***	***/***
17	***/***	***/***	***/***	***/***	83/ 83	83/ 83	***/***	***/***	***/***
18	***/***	***/***	***/***	83/ 83	83/ 83	83/ 83	83/ 83	83/ 83	83/ 83

Figure 27. (Cont'd.)

As would be expected, the three runs with the lowered set point exhibited greater energy consumption than their higher set point counterparts. However, the constant ventilation scheme (in both cases) did not consume nearly twice the amount of the runs where fans were only allowed to cycle for 12 hours. This can be explained as follows. Even if the fans are allowed to operate throughout the night and lower the internal masses temperature, they will consume very little additional energy during their operation. Remember, the fans do not cycle during the day even if left on, if interior temperatures remain below exterior temperatures. Conversely, if fans only cycle during the day, then interior temperatures are much higher, thus allowing the fans to run more often since interior temperatures more often exceed exterior temperatures. Furthermore, BLAST does not account for increased power consumption for startup motor loads, thus the figures are not exact. Since the motors cycle with greater frequency on the constant schedule, the consumption difference should in reality be somewhat greater.

The important detail to recognize is the difference between the daytime and nighttime ventilation schedules. Although their consumption is almost identical, the comfort levels are far from being the same. Moreover, depending on the criterion used regarding the importance of occupant comfort, constant ventilation may very well be justified and desirable if energy consumption is only slightly increased. The operational configurations of a building's mechanical systems can significantly affect occupant comfort while only negligibly affecting energy consumption.

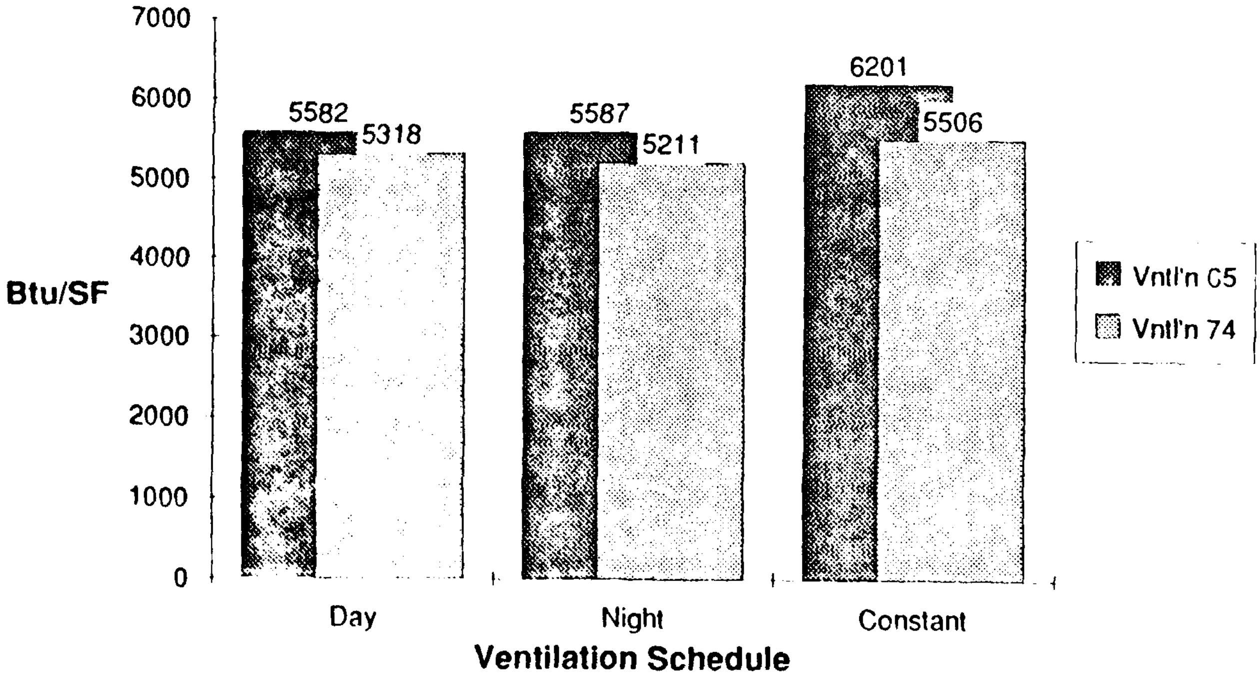


Figure 28. Impact of Ventilation Schedule on Energy Consumption.

4 SUMMARY OF COMFORT ANALYSIS PROCEDURES

The following steps approximate the methodology used to study thermal conditions in the Lajes Field UEPH. This is not the only approach to using the comfort modeling capabilities of BLAST. Every building has unique attributes which must be considered when conducting an in-depth analysis.

BLAST can be used to determine potential problem areas and their extent, and to model the potential viability of alternative solutions. After it has been determined that a comfort analysis is necessary or would benefit a project, and before developing a BLAST deck, a preliminary analysis of the building and climate should be conducted. Observations should focus on building orientation, potential problems with solar loads, influence of surrounding microclimate, and sources of interior heat generation.

The suggested comfort analysis methodology includes 11 steps:

1. Determine the necessity of a comfort analysis and examine climate data.

2. Develop a BLAST deck describing the facility, including the required input for comfort modeling.

3. Examine the weather file to be used, and identify the warmest week of the summer. This week will be used for the comfort analysis. (This establishes a "worst case scenario.")

4. Set comfort parameters to: Metabolic rate = 1.2, Clothing insulation = 0.5, Humidity = -999, and Relative Air Velocity = 0.0. (Assume ventilation system is off and not inducing air motion.)

5. Run the deck for the selected week and observe the PMV values.

6. If the PMV values are within the comfort range, i.e., ±0.5, there should not be comfort problems with the facility. If PMV values indicate a warm or hot interior, various solutions ought to be modeled.

7. Solar radiation is often the primary cause of uncomfortably hot interior conditions. If sunlight is identified as a potential problem, model various alternatives and observe what effect these have on PMV values and interior temperatures. Model alternatives may include overhangs, vertical fins, shading films, exterior shading screens, different types of glazing, etc. If direct solar radiation was a problem, shading the windows should significantly improve interior environmental conditions.

8. If solar radiation is not the problem, or if its elimination does not solve the overheating problem alone, other approaches to modifying the interior environment will be required:

a. Successively increase Relative Air Velocity and see if this lowers the PMV values. If it does, this suggests that the interior environment can be improved by simply inducing air motion. This can be achieved by cycling the ventilation system (without conditioning the exterior air), and by using ceiling fans, opening windows, etc.

b. If interior temperatures and PMV values remain high, try using the forced ventilation option in BLAST.[5]

[5] *BLAST News* (July 1986).

1) Study the mechanical plans and determine ventilation system's CFM.

2) Include a forced ventilation statement in the BLAST deck reflecting the ventilation systems CFM capacity. Schedule forced ventilation to operate during occupied hours and set temperatures to zones which should be ventilated down to a comfortable temperature. Set minimum temperature difference between inside and outside for ventilation to occur to zero.

3) Rerun the deck and observe interior temperature and PMV values. If temperatures continue to be outside the comfort range envelope, experiment with the forced ventilation scheduling. First try extremes, e.g., only cycle the ventilation system during the nighttime to cool the thermal mass of the structure. Also try constant ventilation throughout the day. Unless these simulations are being conducted in a severe environment (e.g., hot humid conditions day and night), there should be improvements to the interior environment.

4) Based on the results of prior runs, it should be possible to deduce the general time period during which it would be beneficial to cycle the ventilation system to cool interior temperature.

9. Once the forced ventilation scheme has been optimized, and if reducing solar radiation loads also improves the interior conditions (even if only marginally), it may be worthwhile to incorporate both of these changes into a BLAST deck and observe how these modifications work in conjunction with each other.

10. Follow-up modeling can use extended periods of time to determine how the building behaves over time and under various conditions.

11. Finally, identified successful alternatives should be evaluated for their life cycle cost using a program such as Life Cycle Cost In Design (LCCID).[6]

These procedures describe the comfort analysis analytic process for a building using forced ventilation for cooling. With slight modification, similar procedures could be used for a mechanically cooled building that is experiencing comfort problems.

[6] Linda Lawrie, *Development and Use of the Life Cycle Cost in Design Computer Program* (LCCID), TR E-85/07/ADA162522 (USACERL, November 1985).

5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study has demonstrated BLAST's capability to incorporate comfort parameters into a traditional energy analysis, and has specified the steps for using BLAST to evaluate existing facilities to find effective, practical, and inexpensive options to maintain thermal comfort.

The Azores case study illustrates BLAST's ability to:

1. Simulate building conditions to do a facility comfort analysis

2. Locate problems that make a facility uncomfortably warm

3. Model conditions at a facility including proposed solutions to identified problems, and to do a comfort analysis under those changed conditions

4. Provide analyses that help to compare and choose between proposed solutions to problems of thermal discomfort, based on effectiveness, cost, and feasibility.

In this case study, BLAST was used to do a comfort analysis by modeling the Lajes Field UEPH with: (1) fans and natural ventilation as a cooling source, (2) shades or window shading as a sun block, (3) exterior insulation as a heat shield, (4) no exterior insulation to allow heat to escape, and (5) mechanical cooling. The program analysis determined that several factors combined to produce the overheating of the UEPH.

BLAST was used in evaluating solutions to the sources of overheating at the UEPH for economy and feasibility. As always, the simplest and most practical measures should be taken first. The comfort analysis showed that the most economical method to cool the building was to allow existing ventilation fans to cycle continuously, and to train the occupants to manually override the automatic controls to avoid overcooling. A second feasible method was to install more effective window shades or window shading (tint) to block out direct sunlight. The program analysis showed installation and use of air conditioning to be a relatively costly alternative, since installation involves major building alterations, and use of air conditioning is not energy-efficient.

Recommendations

In general, it is recommended that a program to resolve facility thermal comfort problems follow a series of controlled steps:

1. Audit of Current Conditions: Once the buildings have been in operation for a period of time, it may be beneficial to examine the current conditions. Relevant issues are: (1) whether the ventilation system is operational, (2) whether dampers, etc. are in proper position, or (3) whether building functional requirements are being met. Buildings will benefit most from being in their best operational state before making any changes.

2. Human Override of Ventilation Controls: Before building modifications are made, occupants should be taught how to control their own environment to make it more comfortable. This includes operating fans at night, shutting fans off during the day, and closing windows and shades during the day. It is appropriate for occupants to assume some responsibility for their own comfort, once they have been taught how.

Two problems may be encountered with this step: (1) the local Base Civil Engineer (BCE) or Directorate of Engineering and Housing (DEH) may not be interested in participating in a building occupant educational program, and (2) occupants must themselves exhibit interest in controlling their environment. Environmental control goes beyond simply adjusting a thermostat. The effectiveness of this step depends on humans and not on mechanical systems. Human inaction rather than economics is probably the greatest limiting factor for the potential success of this step.

3. Solar Control: Mitigation of solar loads can be achieved by various means. Passive building modifications (e.g., installation of shades) should be made before resorting to mechanical cooling processes. It would be imprudent to implement a four-pipe mechanical system without first addressing passive solar control, since the mechanical system would simply counteract solar loads.

Of the various alternatives analyzed, installation of exterior shading screens may offer the best improvement. This option would be relatively economical and would assist the interior regardless of subsequent building alterations.

4. Ventilation System Modification: Again, various ventilating alternatives are available regarding how the ventilation system's controls can be modified. None of the alternatives are expensive, and any one of them will improve interior thermal conditions. If steps 3 and 4 are implemented, step 5 will probably not be necessary. Control of solar radiation and rescheduling of the ventilation system should appreciably improve interior conditions in all but the worst conditions.

5. Mechanical System Modification: This step should only be considered after other alternatives have been implemented and proven to be unacceptable. With a four-pipe fan-coil system, individual room temperatures can be adjusted to the occupants definition of ideal comfort. This is a flexible, but costly, alternative. The BLAST simulations show that complete control of the interior environment is energy and cost inefficient.

APPENDIX A: Azores Weather Summary

Figures A1 to A5 correspond with Tables A1 to A5, and provide a brief overview of climatic weather conditions in the Azores. This data is from an ETAC weather file summary report.

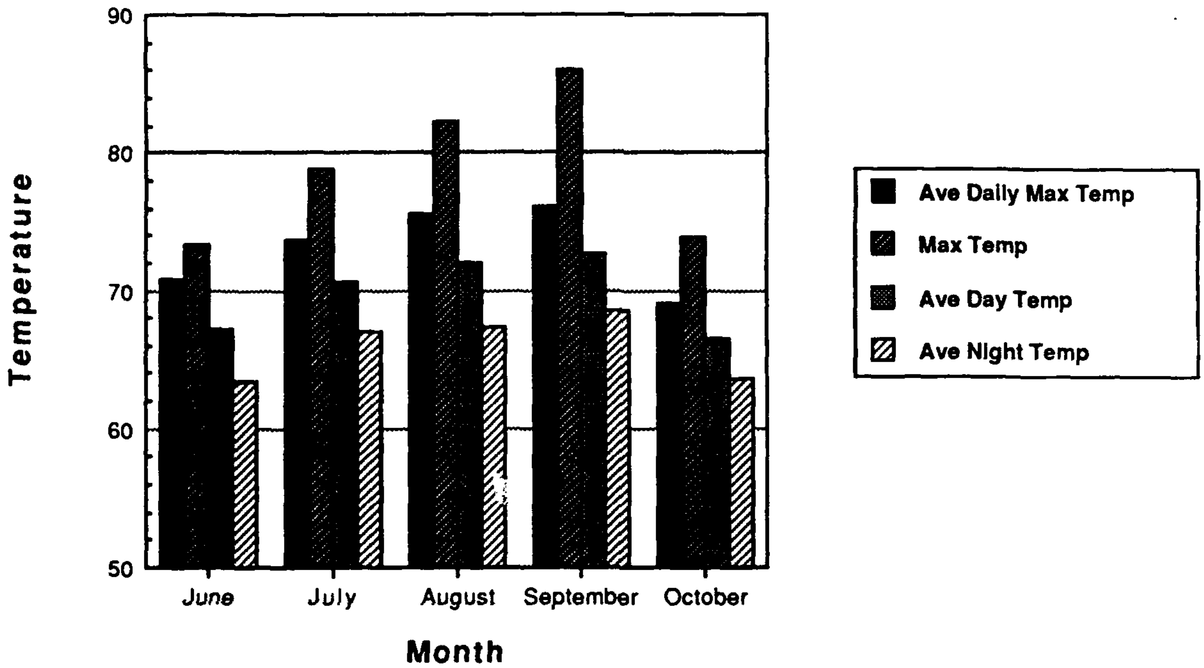


Figure A1. Temperature Data.

Table A1

Temperature Data

Month	Ave Dly Max	Max Temp	Ave Day Temp	Ave Night Temp
June	70.8	73.4	67.2	63.4
July	73.7	78.8	70.6	67.0
August	75.6	82.2	71.9	67.3
September	76.1	86.0	72.7	68.6
October	69.1	73.9	66.4	63.6

APPENDIX A: Azores Weather Summary

Figures A1 to A5 correspond with Tables A1 to A5, and provide a brief overview of climatic weather conditions in the Azores. This data is from an ETAC weather file summary report.

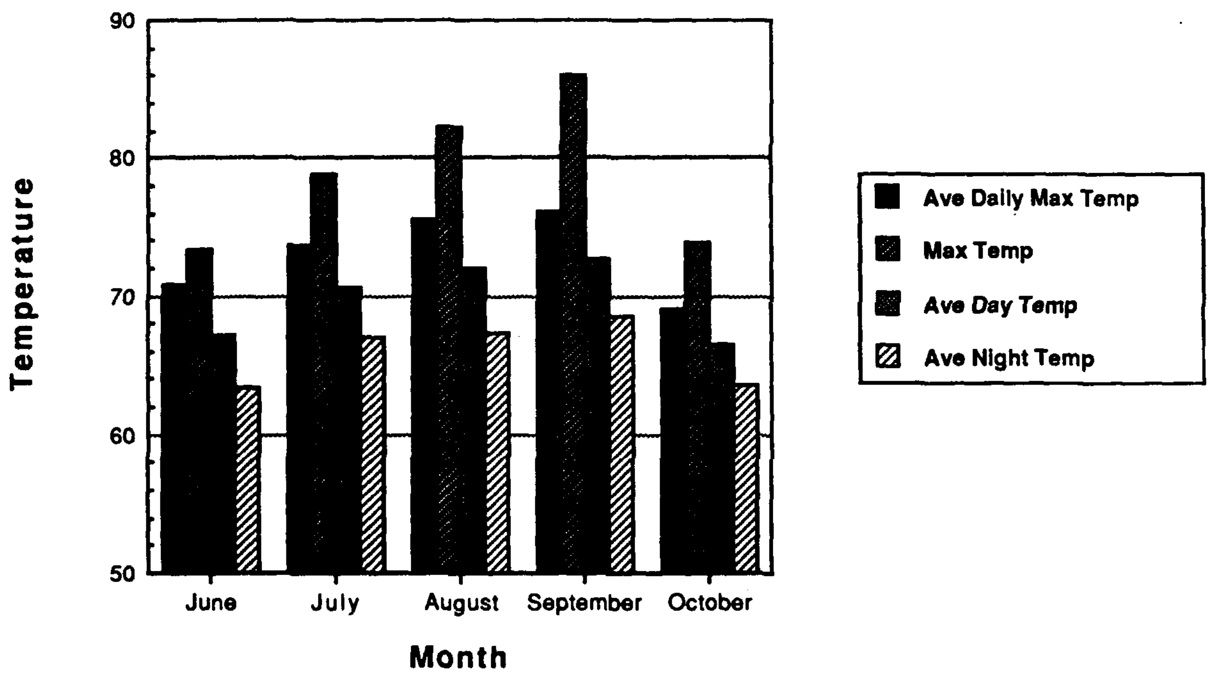


Figure A1. Temperature Data.

Table A1

Temperature Data

Month	Ave Dly Max	Max Temp	Ave Day Temp	Ave Night Temp
June	70.8	73.4	67.2	63.4
July	73.7	78.8	70.6	67.0
August	75.6	82.2	71.9	67.3
September	76.1	86.0	72.7	68.6
October	69.1	73.9	66.4	63.6

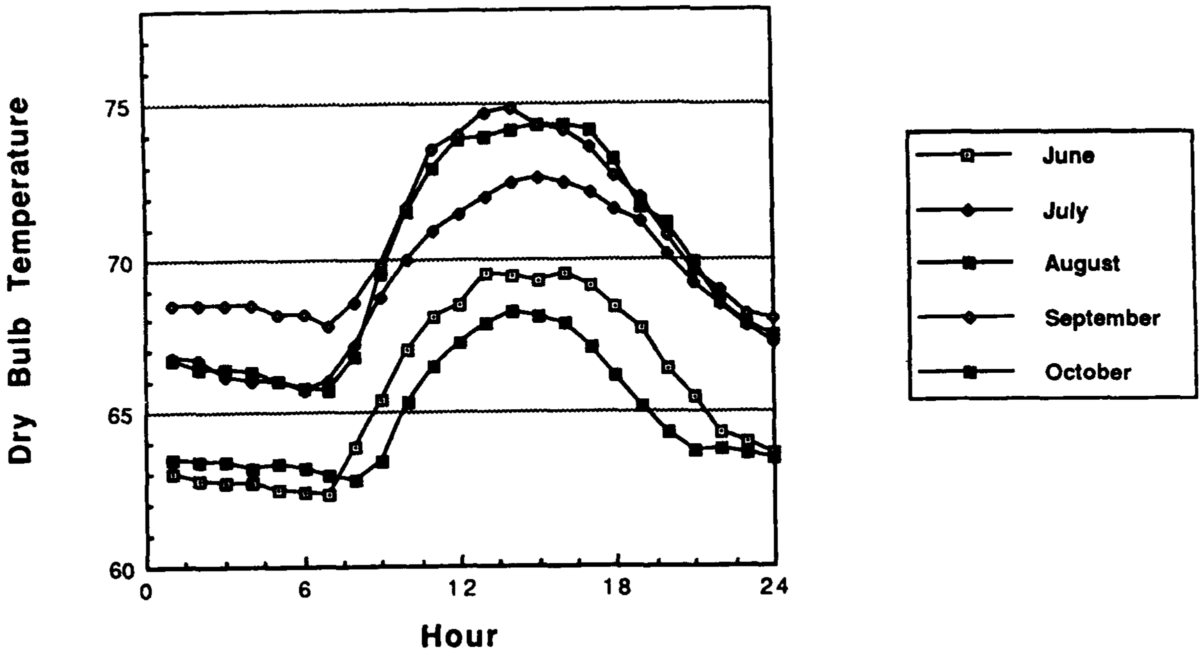


Figure A3. Monthly Average Temperature by Hour of Day.

Table A3

Monthly Average Temperature by Hour of Day

Hr	Jun	Jul	Aug	Sep	Oct
0	63.0	66.8	66.7	68.5	63.5
1	62.8	66.7	66.4	68.5	63.4
2	62.7	66.2	66.4	68.5	63.4
3	62.7	66.0	66.3	68.5	63.2
4	62.5	66.0	66.0	68.2	63.3
5	62.4	65.7	65.8	68.2	63.2
6	62.3	66.0	65.7	67.8	62.9
7	63.9	67.2	66.8	68.6	62.8
8	65.4	68.7	69.5	69.8	63.4
9	67.0	70.0	71.5	71.7	65.3
10	68.1	70.9	72.9	73.5	66.5
11	68.5	71.4	73.8	74.0	67.3
12	69.5	72.0	73.9	74.7	67.9
13	69.4	72.4	74.1	74.8	68.3
14	69.3	72.6	74.3	74.3	68.1
15	69.5	72.4	74.3	74.1	67.9
16	69.1	72.1	74.1	73.6	67.1
17	68.4	71.6	73.2	72.7	66.2
18	67.7	71.2	71.7	72.0	65.2
19	66.4	70.1	71.1	70.7	64.3
20	65.5	69.2	69.9	69.6	63.7
21	64.3	68.5	68.6	69.0	63.8
22	64.0	67.8	67.9	68.2	63.6
23	63.6	67.3	67.5	68.0	63.5

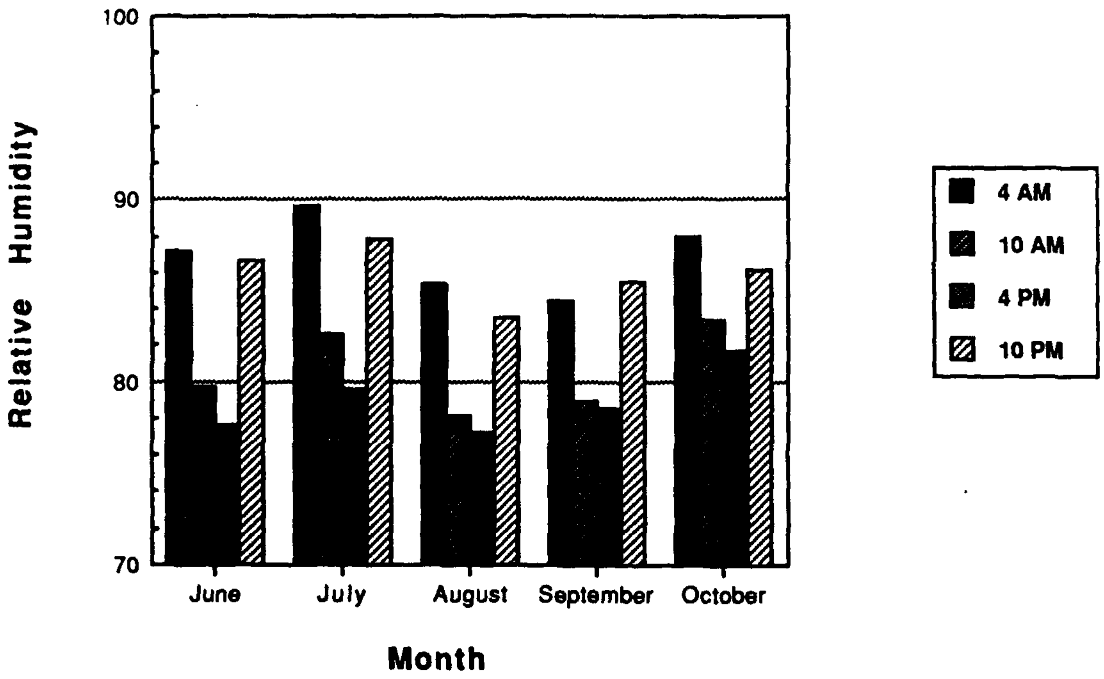


Figure A4. Relative Humidity by Time of Day.

Table A4

Relative Humidity by Time of Day

Month	4 a.m.	10 a.m.	4 p.m.	10 p.m.
June	87.2	79.7	77.6	86.7
July	89.7	82.6	79.6	87.8
August	85.3	78.1	77.2	83.5
September	84.4	78.9	78.5	85.4
October	87.9	83.4	81.6	86.1

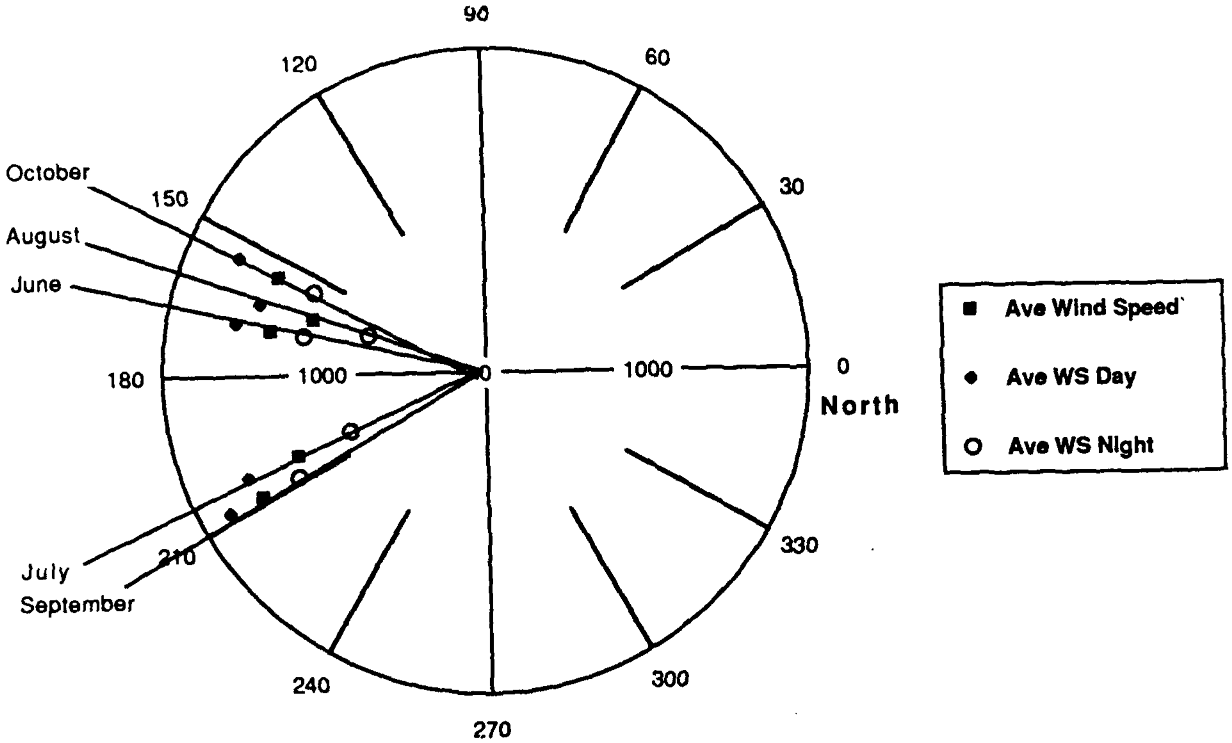


Figure A5. Summer Wind Directions.

Table A5

Summer Wind Directions

Month	Ave Wind Dir	Ave Wind Speed	Ave WS Day	Ave WS Night
June	167.8	1364.8	1577.2	1152.4
July	203.1	1265.6	1611.0	920.2
August	162.1	1114.9	1465.0	764.7
September	208.5	1576.6	1814.6	1338.6
October	154.4	1420.0	1669.1	1171.0

APPENDIX B: BLAST Input Deck

```
BEGIN INPUT;
**************************************
**                                  **
**      CERL COMFORT ANALYSIS       **
**      FOR UEPH FACILITY AT        **
**      LAJES FIELD - AZORES        **
**                                  **
**      ____________________        **
**                                  **
**        18 ZONE MODEL             **
**         MAY 9, 1990              **
**                                  **
**     VENTILATION STATEMENT        **
**   65 MIN TEMP    0.0 DEL TEMP    **
**                                  **
**            AN25M2                **
**                                  **
**************************************
   RUN CONTROL:
     NEW ZONES,NEW AIR SYSTEM,
     REPORTS(ZONE LOADS,SYSTEM,SYSTEM LOADS),
     UNITS(IN=ENGLISH, OUT=ENGLISH);
     TEMPORARY LOCATION:
       LAJES FIELD - AZORES
         = (LAT=38.77,LONG=27.10,TZ=1);
   END;
   TEMPORARY DESIGN DAYS:
       LJUL:SUMMER COOLING-JULY
         = (HIGH=73.70,LOW=64.10,WB=63.60,DATE=21JUL,PRES=401.50,
           WS=1265.60,DIR=203.10,CLEARNESS=0.70,WEEKDAY);
       LAUG:SUMMER COOLING-AUGUST
         = (HIGH=75.60,LOW=64.00,WB=63.40,DATE=21AUG,PRES=401.50,
           WS=1114.90,DIR=162.10,CLEARNESS=0.81,WEEKDAY);
       LSEP:SUMMER COOLING-SEPTEMBER
         = (HIGH=76.10,LOW=65.30,WB=64.30,DATE=21SEP,PRES=401.50,
           WS=1576.60,DIR=208.50,CLEARNESS=0.76,WEEKDAY);
       LJES:SUMMER COOLING-2.5 DESIGN TEMP
         = (HIGH=79.00,LOW=65.30,WB=70.00,DATE=21SEP,PRES=401.50,
           WS=1319.03,DIR=191.23,CLEARNESS=0.76,WEEKDAY);
       LEXT:SUMMER-EXTREME CONDITIONS
         = (HIGH=86.00,LOW=69.26,WB=73.88,DATE=01SEP,PRES=401.47,
           WS=1888.90,DIR=264.20,CLEARNESS=0.78,WEEKDAY);
   END;
   TEMPORARY MATERIALS:
       EARTH 1 FT= (L=1.0000,K=.8000,D=100.0,CP=.200, ABS=.75,TABS=.90,ROUGH);
       CONC SLAB 5 IN= (L=.4166,K=.7576,D=140.0,CP=.200, ABS=.60,TABS=.90,ROUGH);
       CARPET = (R=2.080,ABS=.75,TABS=.90,ROUGH);
       CONC DECK 2 1/2 IN = (L=.2083,K=.7500,D=140.0,CP=.200,ABS=.60,TABS=.90,MEDIUM ROUGH);
       INSUL 6 IN = (L=.5000,K=.0250,D=2.0,CP=.200,ABS=.50,TABS=.90, MEDIUM ROUGH);
       EXT 1 1/2 INSUL = (L=.1250,K=.0208,D=1.8,CP=.290,ABS=.60,TABS=.90,SMOOTH);
       SOUND INSUL 2 IN= (L=.1670,K=.0208,D=1.8,CP=.290,ABS=.50,TABS=.90, MEDIUM ROUGH);
       CLAY TILE= (L=.2500,K=.3100,D=70.0,CP=.200, ABS=.63,TABS=.90,SMOOTH);
       BUILDING MEMBRANE - FELT = (R=.060,ABS=.75,TABS=.90,SMOOTH);
       PLYWOOD 1/2 IN = (L=.0417,K=.0670,D=34.0,CP=.290,ABS=.78,TABS=.90, MEDIUM ROUGH);
       PLYWOOD 3/4 IN = (L=.0625,K=.0670,D=34.0,CP=.290,ABS=.78,TABS=.90, MEDIUM ROUGH);
   END;

   TEMPORARY WALLS:
       EXTERIOR WALLS
         = (CONCRETE - STUCCO 1/2 IN,EXT 1 1/2 INSUL , C8-8 IN HW CONCRETE BLOCK, PLASTER - GYPSUM SA 5/8
 IN);
       SEPERATION WALLS
         = (PLASTER - GYPSUM SA 5/8 IN ,SOUND INSUL 2 IN , AIRSPACE - VERTICAL, PLASTER - GYPSUM SA 5/8 IN);
       REGULAR WALLS
         = (PLASTER - GYPSUM SA 5/8 IN , B1 - AIRSPACE RESISTANCE , PLASTER - GYPSUM SA 5/8 IN);
       ATTIC WALLS
         = (CONCRETE - STUCCO 1/2 IN , EXT 1 1/2 INSUL ,PLYWOOD 1/2 IN);
       SECOND AND THIRD FLOORS
         = (CARPET ,CONC DECK 2 1/2 IN ,B1 - AIRSPACE RESISTANCE, PLASTER - GYPSUM SA 5/8 IN);
   END;
   TEMPORARY ROOFS:
       THIRD FLOOR CEILING
         = (CONC DECK 2 1/2 IN ,AIRSPACE - HORIZONTAL UP ,INSUL 6 IN, PLASTER - GYPSUM SA 5/8 IN);
       BUILDING ROOF
         = (CLAY TILE ,BUILDING MEMBRANE - FELT , PLYWOOD 3/4 IN);
       FIRST AND SECOND FLOOR CEILING
         = (CARPET ,CONC DECK 2 1/2 IN ,B1 - AIRSPACE RESISTANCE , PLASTER - GYPSUM SA 5/8 IN);
   END;
   TEMPORARY FLOORS:
       SLAB FLOOR
         = (EARTH 1 FT ,BUILDING MEMBRANE - PLASTIC FILM ,CONC SLAB 5 IN , CARPET);
       SECOND AND THIRD FLOORS
         = (CARPET ,CONC DECK 2 1/2 IN ,B1 - AIRSPACE RESISTANCE ,  PLASTER - GYPSUM SA 5/8 IN);
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      ATTIC FLOOR
         = (PLASTER - GYPSUM SA 5/8 IN ,INSUL 6 IN ,AIRSPACE-HORIZONTAL UP, CONC DECK 2 1/2 IN);
  END;
  TEMPORARY SCHEDULE (OCC-BED):
    MONDAY THRU SATURDAY=(23 TO 7-1.0,7 TO 8-0.25, 8 TO 16-0.125,16 TO 18-0.5,18 TO 20-0.25,20 TO 23-0.5),
    SUNDAY=(23 TO 7-1.0,7 TO 8-0.25, 8 TO 18-0.5,18 TO 20-0.25,20 TO 23-0.5),
    HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (OCC-COR):
    MONDAY THRU SATURDAY=(23 TO 16-0.0,16 TO 18-0.25, 18 TO 23-1.0),
    SUNDAY=(23 TO 12-0.0,12 TO 18-0.5, 18 TO 23-1.0),
    HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (LTS-BED):
    MONDAY THRU SATURDAY=(23 TO 06-0.1,06 TO 07-1.0,07 TO 16-0.1, 16 TO 23-0.5),
    SUNDAY=(23 TO 06-0.1,06 TO 07-1.0,07 TO 16-0.5,16 TO 23-0.5),
    HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (LTS-COR):
    MONDAY THRU SATURDAY=(23 TO 16-0.1,16 TO 23-1.0),
    SUNDAY=(23 TO 12-0.0,12 TO 23-1.0),
    HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (MINAIR):
      MONDAY THRU SUNDAY= (00 TO 24-0.25),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (VENT-SCH):
      MONDAY THRU SUNDAY=(18 to 6-1.0,6 TO 18-0.0),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (REL-VEL-SCH):
      MONDAY THRU SUNDAY=(18 to 6-1.0,6 TO 18-0.0),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (CONST-OFF):
      MONDAY THRU SUNDAY= (00 TO 24-0.0),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (CONST-ON):
      MONDAY THRU SUNDAY= (00 TO 24-1.0),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY SCHEDULE (SYS-BED):
      MONDAY THRU SATURDAY= (18 TO 6-1.0, 6 TO 18-0.0),
      SUNDAY=(00 TO 24-1.0),
      HOLIDAY=SUNDAY
  END;
  TEMPORARY SCHEDULE (OSA-BED):
      MONDAY THRU SATURDAY=(18 TO 6-1.0,6 TO 18-0.0),
      SUNDAY=(00 TO 24-1.0),
      HOLIDAY=SUNDAY;
  END;
  TEMPORARY CONTROLS (BEDROOM CONTROLS):
      PROFILES:
        STANDARD=(1.0 AT 63.0, .0 AT 64.00);
  SCHEDULES:
        MONDAY THRU FRIDAY=(0 TO 24-STANDARD),
        SATURDAY=(0 TO 24-STANDARD),
        SUNDAY=(0 TO 24-STANDARD),
        HOLIDAY=(0 TO 24-STANDARD);
  END;

PROJECT="BLAST ANALYSIS
              UNACCOMPANIED ENLISTED PERSONNEL HOUSING
              LAJES FIELD,AZORES
              ATLANTIC DIVISION <169>;
 LOCATION=LAJES FIELD - AZORES ;
WEATHER TAPE FROM 01 AUG 83 THRU 31 JUL 84;
GROUND TEMPERATURES=(70,70,70,70,70,70,70,70,70,70,70,70);
CATEGORY CODE=72111;
BEGIN BUILDING DESCRIPTION;
BUILDING="UNACCOMPANIED ENLISTED PERSONNEL HOUSING";
NORTH AXIS= -35.00;
SOLAR DISTRIBUTION= 0;

ZONE 1
WEST BEDROOMS-FIRST FLOOR: ORIGIN:(3.00, .00, .00);NORTH AXIS=.00;
EXTERIOR WALLS : STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (23.33 BY 10.33), STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
EXTERIOR WALLS (244.33 BY 10.33) WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (90.00 BY 5.00) REVEAL(.33) AT (77.00, 2.33) WITH OVERHANGS (244.33 BY 3.00) AT (.00,
7.33);
INTERZONE PARTITIONS : STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
SEPERATION WALLS (244.33 BY 10.33) ADJACENT TO ZONE (13);
SLAB ON GRADE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SLAB FLOOR (23.33 BY 244.33);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 244.33)ADJACENT TO ZONE (2);
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INTERNAL MASS: SEPERATION WALLS(200.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS (440.00 BY 10.33);
PEOPLE=40,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=34.12,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,160.0 HEATING, .00 PERCENT MRT, FROM 01JAN THRU 31DEC;
INFILTRATION=600.00,RL, WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=12000.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP,0.50 EXHAUST FAN PRESSURE,
 0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 2
WEST BEDROOMS-SECOND FLOOR: ORIGIN:(3.00, .00, 10.33);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (23.33 BY 10.33),STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
EXTERIOR WALLS (244.33 BY 10.33)
WITH WINDOWS OF TYPE DOUBLE PANE WINDOW (90.00 BY 5.00) REVEAL(.33) AT (77.00, 2.33)
WITH OVERHANGS (244.33 BY 3.00) AT (.00, 7.33);
INTERZONE PARTITIONS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
SEPERATION WALLS (244.33 BY 10.33)ADJACENT TO ZONE (14);
INTERZONE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 244.33) ADJACENT TO ZONE (1);
INTERZONE CEILINGS : STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 244.33)ADJACENT TO ZONE (3);
INTERNAL MASS: SEPERATION WALLS(200.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS(440.00 BY 10.33);
PEOPLE=40,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=34.12,LTS-BED ,00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,160.0 HEATING, .00 PERCENT MRT,FROM 01JAN THRU 31DEC;
INFILTRATION=600.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=12000.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP, 0.50 EXHAUST FAN PRESSURE,
0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00,VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 3
WEST BEDROOMS-THIRD FLOOR: ORIGIN:(3.00, .00, 20.66);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (23.33 BY 10.33),STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
EXTERIOR WALLS (244.33 BY 10.33)
WITH WINDOWS OF TYPE DOUBLE PANE WINDOW (90.00 BY 5.00) REVEAL(.33) AT (77.00, 2.33)
WITH OVERHANGS (244.33 BY 3.00) AT (.00, 7.33);
INTERZONE PARTITIONS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
SEPERATION WALLS (244.33 BY 10.33) ADJACENT TO ZONE (15);
INTERZONE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 244.33)ADJACENT TO ZONE (2);
NTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
THIRD FLOOR CEILING (23.33 BY 244.33)ADJACENT TO ZONE (18);
INTERNAL MASS: SEPERATION WALLS(200.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS (440.00 BY 10.33);
PEOPLE=40,OCC-BED , AT ACTIVITY LEVEL .40, 70.00 PERCENT RADIANT, FROM 01JAN THRU 31DEC;
LIGHTS=34.12,LTS-BED , .00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,160.0 HEATING,.00 PERCENT MRT,FROM 01JAN THRU 31DEC;
INFILTRATION=600.00,RL, WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=12000.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP,
0.50 EXHAUST FAN PRESSURE,.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 4
SOUTH-EAST BEDROOMS-FIRST FLOOR: ORIGIN:(30.66, 9.33, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(18.66, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (4.67 BY 10.33),STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (73.50 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (27.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)WITH OVERHANGS (73.50 BY 3.00) AT (
.00,7.33);
INTERZONE PARTITIONS :STARTING AT(23.33, 73.50, .00) FACING(.00) TILTED(90.00)
SEPERATION WALLS (23.33 BY 10.33)ADJACENT TO ZONE (10),STARTING AT(.00, 73.50, .00) FACING(270.00)
TILTED(90.00)
SEPERATION WALLS (73.50 BY 10.33)ADJACENT TO ZONE (13),STARTING AT( .00, .00, .00) FACING(180) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (16);
SLAB ON GRADE FLOORS :STARTING AT(.00, 73.50, .00) FACING(180.00) TILTED(180.00)SLAB FLOOR (23.33 BY 73.50);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 73.50)ADJACENT TO ZONE (5);
INTERNAL MASS: SEPERATION WALLS(110.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS(85.00 BY 10.33);
PEOPLE=12,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=10.24,LTS-BED , .00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,48.0 HEATING,.00 PERCENT MRT,FROM 01OCT THRU 30 JUN;
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INFILTRATION=180.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=3600.00, CONST-ON , 65.00 MIN TEMP, 0.0 DEL TEMP,
0.50 EXHAUST FAN PRESSURE, 0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 5
SOUTH-EAST BEDROOMS-SECOND FLOOR: ORIGIN:(30.66, 9.33, 10.33);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(18.66, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (4.67 BY 10.33),STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (97.83 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (36.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)WITH OVERHANGS (97.83 BY 3.00) AT (
.00,7.33);
INTERZONE PARTITIONS :STARTING AT(23.33, 97.83, .00) FACING(.00) TILTED(90.00)
SEPERATION WALLS (23.33 BY 10.33)ADJACENT TO ZONE (11),
STARTING AT(.00, 97.83, .00) FACING(270.00) TILTED(90.00)
SEPERATION WALLS (97.83 BY 10.33)ADJACENT TO ZONE (14),STARTING AT( .00, .00, .00) FACING(180) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (16);
INTERZONE FLOORS : STARTING AT(.00, 73.50, .00) FACING(180.00)TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 73.50)ADJACENT TO ZONE (4),
STARTING AT(.00, 97.83, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 24.33)ADJACENT TO ZONE (10);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 97.83)ADJACENT TO ZONE (6);
INTERNAL MASS: SEPERATION WALLS(150.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS(110.00 BY 10.33);
PEOPLE=16,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT, FROM 01JAN THRU 31DEC;
 LIGHTS=11.64,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE, FROM 01JAN THRU 31DEC;
 CONTROLS=BEDROOM CONTROLS ,64.0 HEATING,  .00 PERCENT MRT, FROM 01JAN THRU 31DEC;
INFILTRATION=240.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0), FROM 01JAN THRU 31DEC;
VENTILATION=4800.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP,
 0.50 EXHAUST FAN PRESSURE,0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 6
SOUTH-EAST BEDROOMS-THIRD FLOOR: ORIGIN:(30.66, 9.33, 20.66);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(18.66, .00, .00) FACING(180.00)  TILTED(90.00)
EXTERIOR WALLS (4.67 BY 10.33),STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (97.83 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (36.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)WITH OVERHANGS (97.83 BY 3.00) AT (
.00,7.33);
INTERZONE PARTITIONS :STARTING AT(23.33, 97.83, .00) FACING(.00) TILTED(90.00)
SEPERATION WALLS (23.33 BY 10.33)ADJACENT TO ZONE (12),
STARTING AT(.00, 97.83, .00) FACING(270.00) TILTED(90.00)
SEPERATION WALLS (97.83 BY 10.33) ADJACENT TO ZONE (15),STARTING AT( .00, .00, .00) FACING(180)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (16);
INTERZONE FLOORS :STARTING AT(.00, 97.83, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 97.83)ADJACENT TO ZONE (5);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
THIRD FLOOR CEILING (23.33 BY 97.83)ADJACENT TO ZONE (18);
INTERNAL MASS: SEPERATION WALLS(150.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS(110.00 BY 10.33);
PEOPLE=16,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=11.64,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,64.0 HEATING, .00 PERCENT MRT, FROM 01JAN THRU 31DEC;
INFILTRATION=240.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=4800.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP,
0.50 EXHAUST FAN PRESSURE, 0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT
END ZONE;

ZONE 7
NORTH-EAST BEDROOMS-FIRST FLOOR: ORIGIN:(30.66, 161.50, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (73.50 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (27.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)WITH OVERHANGS (73.50 BY 3.00) AT (
.00,7.33),
STARTING AT(23.33, 73.50, .00) FACING(.00) TILTED(90.00)EXTERIOR WALLS (4.67 BY 10.33);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (10),STARTING AT(.00, 73.50, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (13),STARTING AT(18.66, 73.50, .00) FACING(.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (17);
SLAB ON GRADE FLOORS :STARTING AT(.00, 73.50, .00) FACING(180.00) TILTED(180.00)
SLAB FLOOR (23.33 BY 73.50);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 73.50)ADJACENT TO ZONE (8);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
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INTERNAL MASS: REGULAR WALLS(85.00 BY 10.33);
PEOPLE=12,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=10.24,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
20.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS , 48.0 HEATING, .00 PERCENT MRT,FROM 01JAN THRU 31DEC;
INFILTRATION=180.00,RL, WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=3600.00, CONST-ON ,65.00 MIN TEMP, 0.0 DEL TEMP, 0.50 EXHAUST FAN PRESSURE,
0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
 END ZONE;

ZONE 8
NORTH-EAST BEDROOMS-SECOND FLOOR: ORIGIN:(30.66, 161.50, 10.33);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00)  TILTED(90.00)
EXTERIOR WALLS (73.50 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (27.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)WITH OVERHANGS (73.50 BY 3.00) AT (
.00,7.33),
STARTING AT(23.33, 73.50, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (4.67 BY 10.33);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (11),STARTING AT(.00, 73.50, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (14),STARTING AT(18.66, 73.50, .00) FACING(.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (17);
INTERZONE FLOORS :STARTING AT(.00, 73.50, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 73.50)ADJACENT TO ZONE (7);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 73.50)ADJACENT TO ZONE (9);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS (85.00 BY 10.33);
PEOPLE=12,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=10.24,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,48.0 HEATING, .00 PERCENT MRT,FROM 01JAN THRU 31DEC;
INFILTRATION=180.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=3600.00, CONST-ON , 65.00 MIN TEMP, 0.0 DEL TEMP,
0.50 EXHAUST FAN PRESSURE,0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50.00, VENT-SCH;RELATIVE HUMIDITY=-999;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 9
NORTH-EAST BEDROOMS-THIRD FLOOR: ORIGIN:(30.66, 161.50, 20.66);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (73.50 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (27.00 BY 5.00) REVEAL(.33) AT (19.00, 2.33)
WITH OVERHANGS (73.50 BY 3.00) AT ( .00,7.33),STARTING AT(23.33, 73.50, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (4.67 BY 10.33);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (12),STARTING AT(.00, 73.50, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (15),STARTING AT(18.66, 73.50, .00) FACING(.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (17);
INTERZONE FLOORS :STARTING AT(.00, 73.50, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 73.50)ADJACENT TO ZONE (8);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
THIRD FLOOR CEILING (23.33 BY 73.50)ADJACENT TO ZONE (18);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
INTERNAL MASS: REGULAR WALLS(85.00 BY 10.33);
PEOPLE=12,OCC-BED ,AT ACTIVITY LEVEL .45, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=10.24,LTS-BED ,.00 PERCENT RETURN AIR, 80.00 PERCENT RADIANT,
10.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
CONTROLS=BEDROOM CONTROLS ,48.0 HEATING, .00 PERCENT MRT,FROM 01JAN THRU 31DEC;
INFILTRATION=180.00,RL,WITH COEFFICIENTS (1.0, 0.0, 0.0, 0.0),FROM 01JAN THRU 31DEC;
VENTILATION=3600.00, CONST-ON , 65.00 MIN TEMP, 0.0 DEL TEMP,
0.50 EXHAUST FAN PRESSURE,0.80 FAN EFFICIENCY,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=50,VENT-SCH;RELATIVE HUMIDITY=-999;
 METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 10
ANCILLARY SPACES-FIRST FLOOR: ORIGIN:(30.66, 82.83, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (78.66 BY 10.33);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33) ADJACENT TO ZONE (4),STARTING AT(23.33, 78.66, .00) FACING(.00)
TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (7),STARTING AT(.00, 78.66, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (78.66 BY 10.33)ADJACENT TO ZONE (13);
SLAB ON GRADE FLOORS :STARTING AT(.00, 78.66, .00) FACING(180.00) TILTED(180.00)
SLAB FLOOR (23.33 BY 78.66);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00)TILTED(.00)
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FIRST AND SECOND FLOOR CEILING (23.33 BY 24.33)ADJACENT TO ZONE (5),
STARTING AT(.00, 24.33, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 54.33)ADJACENT TO ZONE (11);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP, FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 11
ANCILLARY SPACES-SECOND FLOOR  ORIGIN:(30.66, 107.16, 10.33);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (54.33 BY 10.33);
INTERZONE PARTITIONS :
STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (5),STARTING AT(23.33, 54.33, .00) FACING(.00)
TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (8),STARTING AT(.00, 54.33, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (54.33 BY 10.33)ADJACENT TO ZONE (14);
INTERZONE FLOORS :STARTING AT(.00, 54.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 54.33)ADJACENT TO ZONE (10);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (23.33 BY 54.33)ADJACENT TO ZONE (12);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
VENTILATION=0.00,CONST-OFF , 65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 12
ANCILLARY SPACES-THIRD FLOOR: ORIGIN:(30.66, 107.16, 20.66);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(23.33, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (54.33 BY 10.33);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (6),STARTING AT(23.33, 54.33, .00) FACING(.00)
TILTED(90.00)
Separation WALLS (23.33 BY 10.33)ADJACENT TO ZONE (9),STARTING AT(.00, 54.33, .00) FACING(270.00)
TILTED(90.00)
Separation WALLS (54.33 BY 10.33)ADJACENT TO ZONE (15);
INTERZONE FLOORS :STARTING AT(.00, 54.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (23.33 BY 54.33)ADJACENT TO ZONE (11);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
THIRD FLOOR CEILING (23.33 BY 54.33)ADJACENT TO ZONE (18);
INTERNAL MASS: Separation WALLS(110.00 BY 10.33);
VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 13
CORRIDOR-FIRST FLOOR: ORIGIN:(26.33, .00, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33),
STARTING AT(4.33, 244.33, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33);
INTERZONE PARTITIONS :STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
Separation WALLS (244.33 BY 10.33)ADJACENT TO ZONE (1),STARTING AT(4.33, 9.33, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (4),STARTING AT(4.33, 82.83, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (78.66 BY 10.33)ADJACENT TO ZONE (10),STARTING AT(4.33, 161.50, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (7),STARTING AT(4.33, .00, .00) FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (16),STARTING AT(4.33, 235.00, .00)  FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (17);
SLAB ON GRADE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SLAB FLOOR (4.33 BY 244.33);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (4.33 BY 244.33)ADJACENT TO ZONE (14);
PEOPLE=20,OCC-COR ,AT ACTIVITY LEVEL .60, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=8.00,LTS-COR ,.00 PERCENT RETURN AIR, 20.00 PERCENT RADIANT,
20.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
VENTILATION=0.00,CONST-OFF 65.00 MIN TEMP, 0.0 DEL TEMP, FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;
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ZONE 14
CORRIDOR-SECOND FLOOR: ORIGIN:(26.33, .00, 10.33)NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)
WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33),STARTING AT(4.33, 244.33, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33);
INTERZONE PARTITIONS :STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
Separation WALLS (244.33 BY 10.33)ADJACENT TO ZONE (2),STARTING AT(4.33, 9.33, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (97.83 BY 10.33)ADJACENT TO ZONE (5),STARTING AT(4.33, 107.16, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (54.33 BY 10.33)ADJACENT TO ZONE (11),STARTING AT(4.33, 161.50, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (73.50 BY 10.33)ADJACENT TO ZONE (8),STARTING AT(4.33, .00, .00) FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (16),STARTING AT(4.33, 235.00, .00) FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (17);
INTERZONE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (4.33 BY 244.33)ADJACENT TO ZONE (13);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
FIRST AND SECOND FLOOR CEILING (4.33 BY 244.33)ADJACENT TO ZONE (15);
PEOPLE=20,OCC-COR ,AT ACTIVITY LEVEL .60, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=8.00,LTS-COR , .00 PERCENT RETURN AIR, 20.00 PERCENT RADIANT,
 20.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 15
CORRIDOR-THIRD FLOOR: ORIGIN:(26.33, .00, 20.66);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)
WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33),STARTING AT(4.33, 244.33, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (4.33 BY 10.33)WITH WINDOWS OF TYPE
DOUBLE PANE WINDOW (3.50 BY 5.00) REVEAL(.33) AT (.40, 2.33)WITH OVERHANGS (4.33 BY 3.00) AT ( .00,7.33);
INTERZONE PARTITIONS :STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(90.00)
Separation WALLS (244.33 BY 10.33)ADJACENT TO ZONE (3),STARTING AT(4.33, 9.33, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (97.83 BY 10.33)ADJACENT TO ZONE (6),STARTING AT(4.33, 107.16, .00) FACING(90.00)
TILTED(90.00)
Separation WALLS (54.33 BY 10.33)ADJACENT TO ZONE (12),STARTING AT(4.33, 161.50, .00) FACING(90.00)
TILTED(90.00)
SEPARATION WALLS (73.50 BY 10.33)ADJACENT TO ZONE (9),STARTING AT(4.33, .00, .00) FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (16),STARTING AT(4.33, 235.00, .00) FACING(90.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (17);
INTERZONE FLOORS :STARTING AT(.00, 244.33, .00) FACING(180.00) TILTED(180.00)
SECOND AND THIRD FLOORS (4.33 BY 244.33)ADJACENT TO ZONE (14);
INTERZONE CEILINGS :STARTING AT(.00, .00, 10.33) FACING(180.00) TILTED(.00)
THIRD FLOOR CEILING (4.33 BY 244.33)ADJACENT TO ZONE (18);
PEOPLE=20,OCC-COR ,AT ACTIVITY LEVEL .60, 70.00 PERCENT RADIANT,FROM 01JAN THRU 31DEC;
LIGHTS=8.00,LTS-COR ,.00 PERCENT RETURN AIR, 20.00 PERCENT RADIANT,
20.00 PERCENT VISIBLE, .00 PERCENT REPLACEABLE,FROM 01JAN THRU 31DEC;
VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 16
SOUTH-WEST STAIRWELL: ORIGIN:(30.66, .00, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT( .00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 31.00),STARTING AT(18.66, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (9.33 BY 31.00);
INTERZONE PARTITIONS :STARTING AT(18.66, 9.33, .00) FACING(.00) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (4),STARTING AT(18.66, 9.33, 10.33) FACING(.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33) ADJACENT TO ZONE (5),STARTING AT(18.66, 9.33, 20.66) FACING(.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (6),STARTING AT ( .00, 9.33, .00) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (13), STARTING AT ( .00, 9.33, 10.33) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (14),STARTING AT ( .00, 9.33, 20.66) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (15);
ROOFS :STARTING AT(.00, .00, 31.00) FACING(180.00) TILTED(.00)BUILDING ROOF (18.66 BY 9.33);
SLAB ON GRADE FLOORS :STARTING AT(.00, 9.33, .00) FACING(180.00) TILTED(180.00)SLAB FLOOR (18.66 BY 9.33);
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VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 17
NORTH-WEST STAIRWELL: ORIGIN:(30.66, 235.00, .00);NORTH AXIS=.00;
EXTERIOR WALLS :STARTING AT(18.66, .00, .00) FACING(90.00) TILTED(90.00)
EXTERIOR WALLS (9.33 BY 31.00),STARTING AT(18.66, 9.33, .00) FACING( .00) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 31.00);
INTERZONE PARTITIONS :STARTING AT(.00, .00, .00) FACING(180.00) TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33) ADJACENT TO ZONE (7),STARTING AT(.00, .00, 10.33) FACING(180.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (8),STARTING AT(.00, .00, 20.66) FACING(180.00)
TILTED(90.00)
EXTERIOR WALLS (18.66 BY 10.33)ADJACENT TO ZONE (9),STARTING AT( .00, 9.33, .00) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (13),STARTING AT( .00, 9.33, 10.33) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33) ADJACENT TO ZONE (14),STARTING AT( .00, 9.33, 20.66) FACING(270.00)
TILTED(90.00)
EXTERIOR WALLS (9.33 BY 10.33)ADJACENT TO ZONE (15);
ROOFS :STARTING AT(.00, .00, 31.00) FACING(180.00) TILTED(.00)BUILDING ROOF (18.66 BY 9.33);
SLAB ON GRADE FLOORS :STARTING AT(.00, 9.33, .00) FACING(180.00) TILTED(180.00)SLAB FLOOR (18.66 BY 9.33);
VENTILATION=0.00,CONST-OFF , 65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
 RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

ZONE 18
ATTIC SPACE: ORIGIN:(3.00, .00, .00);NORTH AXIS=.00;
INTERZONE FLOORS : STARTING AT( .00, 244.33, .00) FACING(180.00) TILTED(180.00)
ATTIC FLOOR (23.33 BY 244.33)ADJACENT TO ZONE (3),STARTING AT(27.66, 107.16, .00) FACING(180.00)
TILTED(180.00)
ATTIC FLOOR (23.33 BY 97.83)ADJACENT TO ZONE (6),STARTING AT(27.66, 235.00, .00) FACING(180.00)
TILTED(180.00)
ATTIC FLOOR (23.33 BY 73.50)ADJACENT TO ZONE (9),STARTING AT(27.66, 161.50, .00) FACING(180.00)
TILTED(180.00)
ATTIC FLOOR (23.33 BY 54.33)ADJACENT TO ZONE (12),STARTING AT(23.33, 244.33, .00) FACING(180.00)
TILTED(180.00)
ATTIC FLOOR (4.33 BY 244.33)ADJACENT TO ZONE (15);
EXTERIOR WALLS :STARTING AT ( .00, .00, .00) FACING(180) TILTED(90)
ATTIC WALLS ((27.66, .00),(27.66,10.4),(25.5,11.4)),STARTING AT (27.66, .00, .00) FACING(90) TILTED(90)
ATTIC WALLS ((9.33, .00),(9.33,10.4),( .00,10.4)),STARTING AT (27.66,9.33, .00) FACING(180) TILTED(90)
ATTIC WALLS ((23.33, .00),( .00,10.4)),STARTING AT (27.66,244.33, .00) FACING(.00) TILTED(90)
ATTIC WALLS ((27.66, .00),(2.16,11.4),( .00,10.44)),STARTING AT (27.66,235, .00) FACING(90) TILTED(90)
ATTIC WALLS ((9.33, .00),(9.33,10.4),( .00,10.4)),STARTING AT (51,235, .00) FACING( .00) TILTED(90)
ATTIC WALLS ((23.33, .00),(23.33,10.4));
ROOFS :STARTING AT(.00, 244.33, .00) FACING(270.00) TILTED(26.50)
BUILDING ROOF (244.33 BY 27.90),STARTING AT(51.00, 9.33, .00) FACING(90.00) TILTED(26.50)
BUILDING ROOF ( 225.66 BY 27.90),STARTING AT(27.66, .00, 10.40) FACING(90.00) TILTED(26.50)
BUILDING ROOF ( 9.33 BY 2.40),STARTING AT(27.66, 235.00, 10.40) FACING(90.00) TILTED(26.50)
BUILDING ROOF ( 9.33 BY 2.40);
VENTILATION=0.00,CONST-OFF ,65.00 MIN TEMP, 0.0 DEL TEMP,FROM 01JAN THRU 31DEC;
RELATIVE VELOCITY=0.00, CONST-OFF;
RELATIVE HUMIDITY=.83,CONSTANT;
METABOLIC RATE=1.2,CONSTANT;
WORK EFFICIENCY=0.0,CONSTANT;
CLOTHING INSULATION=0.5,CONSTANT;
END ZONE;

 END BUILDING DESCRIPTION;
 BEGIN FAN SYSTEM DESCRIPTION;

TWO PIPE FAN COIL SYSTEM 1
FAN COIL UNIT SERVING ZONES 1;FOR ZONE 1:
SUPPLY AIR VOLUME=6400;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=160;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;
HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;
 AIR VOLUME COEFFICIENT=1.0;
END  OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=6400;
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BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;
ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;
ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=5.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
 END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 2
FAN COIL UNIT SERVING ZONES 2;FOR ZONE 2:
SUPPLY AIR VOLUME=6400;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=160;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=6400;BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;
ENTERING WATER TEMPERATURE=45;LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=5.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 3
FAN COIL UNIT SERVING ZONES 3;FOR ZONE 3:
SUPPLY AIR VOLUME=6400;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=160;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;
AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=6400;BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;
ENTERING WATER TEMPERATURE=45;LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=5.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;
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TWO PIPE FAN COIL SYSTEM 4
FAN COIL UNIT SERVING ZONES 4;FOR ZONE 4:
 SUPPLY AIR VOLUME=1920; ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=48;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
 SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;
HEATING SAT DIFFERENCE=110;COOLING SAT DIFFERENCE=20;
AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
 AIR VOLUME FLOW RATE=1920;
 BAROMETRIC PRESSURE=406.8;
 ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
 LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
 WATER VOLUME FLOW RATE=1.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
 FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 5
FAN COIL UNIT SERVING ZONES 5;FOR ZONE 5:
SUPPLY AIR VOLUME=2560;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=64;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;
AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=2560;BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=2.28;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 6
FAN COIL UNIT SERVING ZONES 6;FOR ZONE 6:SUPPLY AIR VOLUME=2560;
 ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=64;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=2560;
BAROMETRIC PRESSURE=406.8;
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ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=2.28;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
 SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 7
FAN COIL UNIT SERVING ZONES 7;FOR ZONE 7:SUPPLY AIR VOLUME=1920;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=48;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;
AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=1920;
BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=1.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 8
FAN COIL UNIT SERVING ZONES 8;FOR ZONE 8:SUPPLY AIR VOLUME=1920;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
 COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=48;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20; AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=1920;BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=1.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
END SYSTEM;

TWO PIPE FAN COIL SYSTEM 9
FAN COIL UNIT SERVING ZONES 9;FOR ZONE 9:SUPPLY AIR VOLUME=1920;ZONE MULTIPLIER=1;
END ZONE;
OTHER SYSTEM PARAMETERS:
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SUPPLY FAN PRESSURE=0.48914;SUPPLY FAN EFFICIENCY=0.7;
COLD DECK CONTROL=FIXED SET POINT;COLD DECK TEMPERATURE=55.04;
COLD DECK THROTTLING RANGE= 7.2;
HEATING COIL ENERGY SUPPLY=HOT WATER;HEATING COIL CAPACITY=48;
MIXED AIR CONTROL=FIXED PERCENT;
GAS BURNER EFFICIENCY=0.8;
SYSTEM ELECTRICAL DEMAND=0.0;
HOT DECK CONTROL=FIXED SET POINT;HOT DECK TEMPERATURE=180;HEATING SAT DIFFERENCE=110;
COOLING SAT DIFFERENCE=20;
AIR VOLUME COEFFICIENT=1.0;
END OTHER SYSTEM PARAMETERS;
COOLING COIL DESIGN PARAMETERS:
AIR VOLUME FLOW RATE=1920
 BAROMETRIC PRESSURE=406.8;
ENTERING AIR DRY BULB TEMPERATURE=80;ENTERING AIR WET BULB TEMPERATURE=67;
LEAVING AIR DRY BULB TEMPERATURE=60.4;ENTERING WATER TEMPERATURE=45;
LEAVING WATER TEMPERATURE=54.6;
WATER VOLUME FLOW RATE=1.7;
END COOLING COIL DESIGN PARAMETERS;
EQUIPMENT SCHEDULES:
SYSTEM OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL HEATING OPERATION=ON,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
FAN COIL COOLING OPERATION=OFF,FROM 01JAN THRU 31DEC;
MINIMUM VENTILATION SCHEDULE=MINAIR,FROM 01JAN THRU 31DEC;
MAXIMUM VENTILATION SCHEDULE=MAXOA,FROM 01JAN THRU 31DEC;
SYSTEM ELECTRICAL DEMAND SCHEDULE=ON,FROM 01JAN THRU 31DEC;
END EQUIPMENT SCHEDULES;
 END SYSTEM;
END FAN SYSTEM DESCRIPTION;
 END INPUT;
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